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An Introduction *to* Experimental Psychology

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An Introduction *to* Experimental Psychology

by

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DEDICATED TO MY MOTHER

LOUISE GARBE FINNER

Preface

THE course in experimental psychology here offered attempts to present scientific psychology as an integral part of the field of science. It assumes that psychology possesses a common heritage of the scientific method and differs from other sciences only in the problems with which it deals.

For a course so conceived a wide range of problems presents itself, and a choice among them is imperative. The selection here made places the knowledge of the individual and of the group on a level with that which deals with general and common aspects of people. This recognition of the individual has inhered in experimental psychology since its beginning. The stress on applying psychology to concrete problems must give increasing emphasis to the study of a particular person or group, and this is reflected in laboratory practice. The course definitely aims to impart knowledge of the subject to the subject, and of the group to the group. Fortunately, this objective does not preclude the study of the general nature of responses, irrespective of how they manifest themselves in a particular person.

In their comprehensiveness the experiments are neither research projects nor simple demonstrations. Each experiment endeavors to reveal facts that are probably new to students, and aims to present what in general can be acquired in no other way. The experiments strive to impart the conviction that something was actually discovered. The adaptability of the course to particular situations and needs has been kept in mind; the wealth of experimental literature will often suggest other studies and different methods. An introductory course possibly serves its purpose best if it gives a general and relatively simply survey of the field, and provides for adaptation to particular situations and needs.

For devoted work in trying with learners every aspect of the course, it is a pleasure to acknowledge my indebtedness to Dr. Mildred Burlingame, Dr. Christian Paul Heinlein, Dr. Hugh L. Waskom, Dr. Elizabeth Gordon Andrews, and Dr. Dorothy Rose Disher. The students who, in their work and in themselves, are represented in many details, are too large a number to mention individually, but special acknowledgment is due to Christine B. Scarborough for work on the manuscript.

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Part I

THE FIELD TO BE INVESTIGATED AND THE SCIENTIFIC APPROACH TO ITS PROBLEMS

Science is the base upon which is reared the civilization of today. *(From page xiv of the Introduction to the translation of Georgius Agricola's* De re metallica, *by Herbert Clark Hoover and Lou Henry Hoover.)*

Do not believe anything on hearsay; do not believe traditions because they are old and handed down through many generations; do not believe anything on account of rumors or because people talk much about it; do not believe simply because the written testimony of some ancient sage is shown thee; never believe anything because presumption is in its favor, or because the custom of many years leads thee to regard it as true; do not believe anything on the mere authority of teachers or priests. Whatever, according to thine own experience and after careful investigation, agrees with thy reason and is conducive to thine own weal and to that of all other living beings, that accept as truth, and live accordingly. *(Buddha. Quoted in* Kadelpian review, *May, 1932, p. 471. Reprinted by courtesy of Kappa Delta Pi Society.)*

If to an increasing degree we have the security of sound public opinion, if the extravagances and diatribes of political appeal fail in their object, and if, notwithstanding the apparent confusion and welter of our life, we are able to find a steadiness of purpose and a quiet dominating of intelligence, it is largely because of the multitude of our people who have been trained to a considerable extent in scientific method, who look for facts, who have cultivated the habit of inquiry and in a thousand callings face the tests of definite investigations. With scientific applications on every hand, the American people are daily winning their escape from the dangers of being fooled. *(Chief Justice Charles E. Hughes, in an address at the Washington meeting of the AAAS, December 29, 1924.)*

CHAPTER 1

The Scientific Method Applied to Problems of Life

The chapters which follow have a twofold purpose. First, they aim to describe the nature of science and how the scientific method deals with problems of human life; and, second, they attempt to reveal to each student certain facts of his own nature and of human nature in general.

The importance of the second aim, that of getting objective facts about one's own nature as well as about that of others, can be shown only through the results of experiments. It is well, however, to recognize at the outset how little each of us really knows about himself. Probably only in the few fields in which we compete directly with others do we ever discover whether we excel or whether we have inferior endowments and abilities. This ignorance of one's self and of others leads to serious consequences. The loss in distinctive capacities that remain unproductive is undoubtedly large, both to the individual concerned and to society; conversely, the common practice of attempting to develop capacities which exist only at a low level has in it the germ of disappointment and failure. To these individual disappointments and failures must be added the social waste that results from intrusting important work to the mediocre and the unfit.

The other objective, that of revealing how science deals with questions of life, again awaits actual experimentation to give it meaning. For a century or more, life at all levels has been taken into the laboratory, and the established knowledge in many fields is unbelievably large. A bibliography on rhythm assembled before 1920 contains over 500 titles; the studies of the rat, the best known of all animals, fill thousands of pages; the task of organizing the work on the speed of reaction that has been done during the past 50 years has been attempted, but it remains incomplete. Similar statements can be made for many other fields of psychology. The view that science cannot deal with the phenomena of human life belongs to an age which we have fortunately outgrown.

The paragraphs which follow attempt to define the field of science in which psychology has its setting, and to describe the more general aspects of scientific work.

The meaning of science. Science may be defined from two points of view. It is: (1) a body of verified knowledge in a systematized and organized form; and it is (2) the method by which such knowledge is gained. Each of these definitions by implication includes the other. Thus, the view that science is *verified* knowledge assumes that the method that characterizes science was used in gaining the knowledge, since verification would be possible in no other way. Similarly, the definition of science as a method of discovery implies the establishing of facts and their organization into systematized knowledge: these are the products of scientific endeavor. The truth emphasized in the definition of science as method is that no body of knowledge, even if true and well organized, can be considered scientific unless the method by which it was established is known and unless this method conforms to certain standards. In the definition of science as verified and systematized knowledge emphasis is given to the fact that the idle manipulation of apparatus and the blind following of method, since it leads to no results, is not science.

Knowledge of facts without the knowledge of how they were discovered, it has been pointed out, does not constitute science. The information in the possession of primitive people on the curative properties of substances illustrates this fact; the use of cod-liver oil and of certain vegetables antedates the scientific investigations on the effects of vitamines; digitalis as a remedy for certain heart troubles did not become a part of the scientific store of knowledge until a physician purchased the secret of its use from an uneducated woman; quinine was used in the treatment of malaria long before it was prescribed by the physician—the common names "fever tree" and "Florida quinine tree" for a species which was reputed to be effective in the treatment of malaria, suggests tragically the blind groping of the mind ignorant of the method of science. In the laboratories of physiology the substances were studied for their specific effects by proven methods, and the knowledge then became scientific. Early practices in such fields as agriculture, personal hygiene, and the making of implements are often surprisingly sound, but such knowledge does not belong to the realm of science.

The correlative statement that careful methods of investigation without resulting knowledge do not constitute science is more difficult to illustrate, since some fact is generally discovered. However, the hurried and rather aimless efforts of would-be inventors, and the elaborate study of problems that have little meaning, may possibly be excluded from the scope of science. Stern, the German student of language development in children, criticizes much painstaking work in the field on the grounds that it only proves what was already evident or that the new information is inconsequential.

The two aspects of science here described can be readily seen in any of

the sciences. In the relatively new field of gland secretions, for example, both a body of organized knowledge and highly specific methods of investigation are in process of development. In the field of knowledge we have information, partly organized, on the relation of physical growth to the functioning of the pituitary gland, on the source of cretinism in the defective thyroid, on the part that the adrenals play in emotions, and many other facts on the relation of secretions to the life process. The methodology paralleling this development of knowledge includes, among many other procedures, the technique of removing glands from animals, the careful observation of the enlargement or the atrophy of certain glands, and the injection of gland extracts—all studied in relation to specific consequences in the organism. The methods of experimentation and the body of established facts develop side by side, and both are included in the science of endocrinology.

An identical division of science into content and method is seen in psychology; the two aspects are so clearly distinguished that each may be organized into a course of study, with relatively little attention to the other. The known subject matter of psychology is presented in the texts: what has been discovered about emotions, the nature of human motives, the learning process, or any other fact of life. The methods of investigation are presented in the laboratory. More broadly stated, the texts on psychology present in a condensed and also organized form the known facts of the science, with a view to bringing out their meaning for life. The laboratory course, on the other hand, aims to give through first-hand experiences a conception of the methods by which these facts were established, how they became organized, and how their meaning for life was derived. The two parts of the course thus make complementary contributions to the field as a whole. Some of the topics to be investigated in the laboratory may in themselves not give results that are important, but they will serve to show how truth in the field of human nature is established.

A subsequent section (chapter 2) will describe in some detail the essentials of the method that constitutes science. The method centers around the experiment, and the general method of conducting the experiment and the large aims of the course need to be understood as the student enters the laboratory.

General directions for experimentation. The detailed method of conducting an experiment can be made clear only with a particular experiment in question. Certain routine matters should, however, be understood before the work is begun, and certain objectives must be recognized if the course is to give the largest returns.

For individual studies, generally two people must coöperate: the experimenter (*E*), who conducts the experiment, and the subject (*S*) on

whom the experiment is performed. A scribe to record the results will often facilitate the work. The experimenter and the subject alternate in their duties. When the nature of the experiment does not make it impossible, each should act both as experimenter and as subject.

In the conduct of the experiment certain matters are essential to success. The original data should be distinctly labeled. The facts should be recorded in such a way that students can go back to the original notes to answer questions. The directions for the experiment need to be followed very closely. It happens at times that because the directions are changed in a small particular the subject performs an entirely different experiment —and the results show it.

We know little from actual studies on students what form of report is most helpful to them. Some laboratories require a full account which would give complete information to an outsider on the problem investigated, the manner in which the investigation was conducted, the results obtained, and the meaning of these results. This form of report is of unquestioned value for certain problems. Other laboratories ask for a report which, taken in conjunction with the manual, would give this complete knowledge.

Personal factors in experimentation. The preceding paragraphs discussed some of the requirements of investigation in so far as these are due to mechanical features of the work. The more fundamental factors in successful experimentation, however, lie in the individual himself. These personal factors play a part in all three phases of an investigation: (1) acting as subject; (2) observing the responses of others or of one's self; and(3) interpreting the data. Only general suggestions are possible before experiments are introduced.

Trained subjects are consistent. One of the best ways by which a student can judge whether he has developed ability as a subject is to note the regularity or consistency of his responses. Extreme scores, either large or small, are found more commonly in the novice. Also, the scores at different stages of an experiment should show a definite relationship, possibly a tendency for all to become larger or smaller. A performance record that shows abrupt changes may indicate a poor subject. Often it is possible to repeat certain experiments and compare the results. Very close agreement between the records for different days is found in trained people—unless, of course, some new condition in the environment or within the person would necessarily lead to a different response. It is true of each person, in a very real sense, that his performance is as characteristic of him as is his stature.

As an observer of others and as an interpreter of data, the student needs a critical and an objective attitude. Such attitudes are not only essential for scientific work, but often constitute the larger values that a course in

experimental psychology aims to impart. Any attitude is probably a by-product of performing tasks that require that attitude, but the student is helped by being made conscious of the desired result.

A critical attitude required. The student should develop a questioning, a critical attitude toward the facts of life. Today a great deal of credulity is found with reference to questions of human nature. A characteristic of Steinmetz illustrates what needs to be striven for. Early as a student he learned from a teacher never to accept a conclusion until he had examined the facts from which it was drawn and scrutinized the process by which it was derived. Not only did this critical outlook lead him to the discovery of errors and false conclusions in the work of others, but it developed in him an approach to problems without which his achievements would have been impossible.

It happens that in human affairs the questioning attitude is especially important. As will be shown in a subsequent section (chapter 6, on attention), the human being is so constituted that unusual and exceptional facts impress him more than do the large number of common events. He accordingly draws his conclusions, not from all the facts that bear upon a problem, but from the few exceptional ones of which he took note. This tendency to error appears not only in the laboratory, but is often played upon in our everyday life. We are given the names of those who became well after using a certain preparation, and not of those who remained ill. We hear of those who won in a venture, not of those who lost. The success of the few by spectacular means makes us oblivious to the slow, plodding methods that are the rule of life. Only a critical attitude will make it possible for the truth to prevail.

The need for an objective point of view. A second required attitude which should be used in and grow out of the solution of the problems of human behavior is that of objectivity. The facts bearing upon a problem, not individual views or personal prejudices, should determine the answer. The person who is guided by the essential facts in a problem is *objective;* he who is guided by his likes and dislikes, or by facts other than those bearing upon the problem, is *subjective*. Pasteur, whose whole life is worth studying for the insight it gives into the worth and meaning of the scientific spirit, revealed the objective attitude when he said: "It is a question of fact; when I took it up I was as ready to be convinced that spontaneous generation exists as I am now persuaded that those who believe it are blindfolded." The subjective attitude is held by most parents with reference to their children—personal opinions and wishes, not facts, determine what they regard as true. It is held by many people on matters pertaining to their political party, their religion, and their vocation. Almost everybody is intensely subjective with reference to his own personal characteristics. Few attain the degree of objectivity necessary to evaluate

themselves accurately, and still fewer are able to plan a career which will take into account the actualities of their own beings—their weaknesses, the capacities in which they excel, particular abilities which lie latent, and other facts which should control.

Students should be forewarned to take the weaknesses that may be discovered in them with equanimity. There need be no discouragement about poor records. Every person above the level of the low-grade defective is sufficiently complex to possess capacities upon which, if they are properly used, a life may be built. It is also found that in many fields certain weaker capacities give the greater promise of success. At any rate, it is better to choose and plan an enterprise with a full knowledge of one's weaknesses, rather than to undertake tasks blindly. Ignorance of the complete facts will in no event lead to achievement; too often this ignorance is the cause of the tragic failures we see about us.

Questions and Topics for Discussion

1. What work of a banker will require an objective attitude? How will objectivity of view affect the decisions of a judge?

2. Could a case be made for the view that personal likes and dislikes, rather than the essential facts, should control in certain situations?

3. Illustrate the constancy of behavior of people you know. If the forms of behavior that we can readily see are consistent enough to be typical of a certain person, should we expect those forms that we can measure to show consistency?

4. Would a person in whom no change had occurred, upon being put for a second time in the same environment (including the same stimulation), give the same response?

5. Give an illustration that has come under your observation of the need for a critical attitude.

6. One function often given for college work is that it enables people to discover themselves. Illustrate what is meant by this statement. Observe throughout the course whether the general college life or the laboratory gives the more valuable information.

CHAPTER 2

The Subject Matter of Psychology and the Methods of Investigation

The realities of life with which psychology deals cannot be briefly named so that the content of the science will be clearly differentiated from every other field of inquiry. For most of the older sciences this can be done with some assurance of being understood. Thus, the science of botany will center its work about plants, zoology about animals, physics about matter and energy, chemistry about the composition of substances and their transformation, geology about the history of the earth and its life, and so on. For psychology we can profitably begin the work by thinking of its subject matter as the behavior and consciousness of a living organism.

This apparent division of life into two realities raises questions which at present are not to be answered in the laboratory. Consciousness and behavior are regarded by many critical thinkers not as distinct or as different, but as two views of the same reality. When I view my own reaction my description will be in terms of consciousness; when another views the same reaction his description will be in terms of behavior. Both of us are viewing the same fact, but our description of it is in different words.

The meaning of behavior. Behavior is always in a muscle or a gland, and consists of movements or other activities (becoming tense, producing secretions, changing electric resistance—these may be movements, but they are not unequivocally classified as such). These activities of muscles and glands can be observed like any other happenings in the physical world about us. Studies of them are objective and employ a method which is described by that adjective: the *objective method.*

Although all forms of behavior can be reduced to the actions of muscles and glands, it is not in these elementary reactions that psychology is primarily interested. Sometimes this fact is brought out by workers in the field when they say that they study *socially significant* behavior or *adaptive* behavior. This shows that the primary interest of the science is in studying the behavior of the person as a whole. What initiates the response in a person? How are the responses modified? What traces of

former responses can be found when they have not been used for a day or a year? How quickly can certain material be learned? How does the ability of a child differ from that of an adult in this respect?

These questions illustrate what is meant by a problem in behavior. Most of the work in the course before us is with this type of question. The problem here indicated, together with many others discussed in the text, should lend significance to the description of life in terms of behavior.

The meaning of consciousness. Consciousness, as here used, means awareness and nothing else. We assume that the perfectly adjusted automobile goes through all its movements without being aware of them, or of the strain exerted on its parts, or of the heating of its engine. The human organism, however, is aware—conscious—of what occurs. It is aware that it moves, of the load it carries, of the increasing warmth, of the pressure on different parts of the body. It is conscious not only of what happens and of what it is doing, but it is conscious of itself—it is aware of its own organism and of its own acts.

This consciousness is not always the same; it may be awareness of pain or of sound; it may consist in knowing what a particular object is; it may be fear or a sentiment. The awareness of pain or of sound can appear only with reactions of muscles and glands as the component of a total reaction, but its forms and its varied manifestations need to be studied. Science here comes closer to what we think of as the personal life of the individual than anywhere else in its large domain.

The method of studying the reaction from the point of view of the observing individual requires that the person examine his own conscious life. Technically, the method is known as *introspection*. Since the awareness of only one person can be observed by each individual, the conclusions based on data obtained by this method have a limited scientific validity. Science cannot use them to form generalizations as safely as the data obtained by objective methods. A very large proportion of psychological investigations at the present time use objective methods entirely.

Qualitative and quantitative data. Both the method of objective observation and that of introspection give two distinct types of facts. The first type of fact is the answer to the question, What is the response like? Is it an awareness of blue or of green, or of pain? Is the reaction one of knowing an object? Is there any awareness of earlier experiences similar to this one? Does the response involve changes in breathing or in the activity of the salivary glands? Are smooth or striped muscles affected? Was the adapting reaction satisfactory? All studies which answer such questions are *qualitative*.

The second type of fact obtained answers the question, How extensive, or how strong, or of how long a duration was the response? With what

force did the responding muscle pull? How many errors were made? What degree of saturation was the blue? How vivid was the imagery? How intense was the pain? Experiments which search for this type of fact are *quantitative.*

Both qualitative and quantitative descriptions are needed to give complete knowledge of human behavior and consciousness. Qualitative studies bring out those facts in which people tend to be alike—they describe, they show what human nature is like. Quantitative experiments reveal the differences in people. All normal individuals respond to musical sounds; one, however, recognizes that there is something wrong with the tone if a violin string makes ½ of a vibration too many in a second, and another will not recognize this if the number is 10 too many. All adults have the ability to repeat a certain number of figures after they have read or seen them; some, however, will reproduce only 3, whereas others will give over 10. We differ in the time required to make reactions, in the tendency to make errors, in the number of repetitions required to memorize a poem, in the amount of it retained after a week—in probably every capacity or trait that can be named. So large is this topic that to present it adequately courses in the psychology of individual differences are often organized.

To avoid confusion it should be pointed out that the terms quality and quantity (or intensity) have acquired a technical meaning when applied to the modes of sensory response. The distinctions among responses such as warm, tone, blue, pressure, sweet, and the like are commonly recognized as being qualitative; similarly, the distinctions between a loud and a soft tone, an intense and a faint red, a strong and a weak taste, a mild and an acute pain are describable in terms of intensity. For most sensory responses the distinction is readily made, but for some responses a change in intensity appears to result in a new quality. Thus, a change in the intensity of certain colors seems to give a new color quality.

It is now possible to give a more complete description of the field studied by psychology. Psychology is the scientific study of the adaptive responses that occur when a living organism is stimulated. In the normal adult individual these responses may be observed either introspectively by the subject himself, or objectively by others. Observation on the part of the reacting subject or by others yields two kinds of facts, qualitative and quantitative; the complete description of a response requires both sets of facts.

The method of science. The preceding chapter discussed the nature of science. We now need to amplify the discussion on science as a method of investigating. What is meant by saying that psychology makes a *scientific* study of behavior and consciousness?

The method of science is twofold: first, it is a method of establishing

facts either quantitative or qualitative; and, second, it is a method of discovering relations among facts or of seeing them as a unit.

How science proceeds to discover facts. For the discovery of facts the method of science is basically that of *observation.* The farmer who goes to his field to see whether the seeds have sprouted is using the method of the scientist. He would not be a scientist in establishing this fact if he based his information on the statement of another person or if he inferred it from the conditions of the weather.

The point to be stressed is that science depends always on observation. This observation may, of course, be by means of the ear, through touch or taste, or through any other sense organ.

The scientist observes. But experience has taught him to do this accurately. He knows, first of all, that he must *isolate the facts* which he wants to observe. To look at an involved situation and then attempt to report on every aspect of it violates this principle. The reports of different people on the same event—say, an automobile accident—are often contradictory. This illustrates the truth that we cannot observe a complicated event with the hope of getting accurate data. The scientist looks at one object or event and disregards everything else except as it bears on what is being observed.

Secondly, in making observations the scientist *controls the events and the conditions that bear on them.* A fact will not be the same under one set of circumstances as under another. The reporting of anything so conditioned is meaningless unless the attending circumstances are made a part of the report. The thinking on many of the complex problems of modern life is inconclusive because the central facts appear with innumerable attending conditions that vary. The event is not observed under controlled conditions and, consequently, we do not know the facts in their setting. To ascribe, for example, undue influence to the effect of a single painting on the lives of children in the home is unscientific, because other controlling influences are not given consideration. The general observations on the occurrence of crime are equally unconvincing because many of the conditions that go with crime escape the observer.

Science expects, thirdly, that the facts in isolation and under control are to be reported by a *trained observer.* A simple fact, such as the amount of rain that falls during a certain day, requires training in the observer for its correct determination. The untrained person will not find the object plainly visible in the microscope. So important is this element of training for accurate observation that research centers consciously train young men and women in order that progress will not be too seriously interrupted if one of the older workers must drop from the ranks. The ability to make certain observations has in perhaps all of the sciences been limited to a comparatively few individuals.

Fourthly, to improve the accuracy of his observations the scientist often makes use of mechanical devices to report facts for him. He employs the photographic film to fix permanently what passes in a moment; or a chronoscope that is started and stopped by the reactions that are being timed; or he arranges electric contacts that will report the trembling of the hand which the eye cannot see.

Finally, the scientist assures the accuracy of his observations by providing for the *repetition of the events* which he is studying. The facts must be the same when he observes them a second or a third or a tenth time. And, more important, it must be possible for other workers in the field to repeat his observations; only after agreement has been found among several observers are the facts considered established.

The approach here incompletely described constitutes the method of science by which it assures itself that the facts on which it builds are securely established. When these conditions are consciously planned we have an *experiment.* An experiment is observation, with the fact to be observed in isolation, with the conditions bearing on it under control, with the possibility of repeating the observation provided for, and with the accuracy of the observations safeguarded by training in the observer and, if possible, by mechanical devices.

The possible relations among facts. First, then, science is concerned with the establishing of facts. But facts alone never constitute a science. They must be organized, related to one another, seen as a unit, or, as everyday language has it, "explained." The first unified view or explanation of a number of facts is an *hypothesis.* Boulders of many sizes dot the Canadian prairie. To primitive man this isolated fact required no relating to other facts; it figured in his myths and in his stories of the chase, but it was not seen in relation to other facts. The inquiring mind appeared and was puzzled by the strange phenomenon; the hypothesis that the last remnants of an eroded mountain lay scattered about was suggested; another spoke of the possible volcanic origin of the rocks. But additional facts were discovered: the rocks were smooth and had no sharp edges; they were of different composition from the stone layers exposed by the erosion of streams; in color and structure they resembled the rocks in the ranges hundreds of miles northward. The first hypothesis no longer took into account what was known, and a new explanation grew out of the larger body of facts; or, what is the exact equivalent, the larger number of facts was seen as a unit.

This more probable explanation is a *theory.* One suggested a great flood; another the warping of the earth's surface which moved layers of rock; a third an ice sheet in prehistoric times. We would still be at the level of theory if additional facts had not been found. Scars were seen on the boulders and on the sides of neighboring cliffs. Evidence was found

that rivers had flowed through the territory now drained otherwise. Land stretching for hundreds of miles had the contour of a lake basin, and the elements gained from aquatic life. The low, irregularly placed hills of the region appeared to be deposits from some source.

None of the many facts found was in conflict with the explanation that a glacier had once covered the region, and on melting had left the boulders —all facts were in accord with this view and it became the accepted conclusion. The related facts now constitute an interesting story on the geographic history of the region. This episode when seen in relation to other facts gives rise to the systematized and organized knowledge of a chapter in a geology text. The final stage of seeing facts in their relation—of explaining—has been reached.

When organized knowledge deals with phenomena that occur in sequence, the description of this sequence is a *law;* as, the law of gravity or the law of Mendelian inheritance. When we think of a law in its general application to particular situations, we speak of it as a *principle;* if its application is more specific we call it a *rule.* The statement of the law or of the principle in mathematical language is a *formula.* Central in all this discussion for those who would understand the nature of science is the truth that "The man of science does not endeavor to invent law, but only to discover it. . . . . . Natural laws are not man-made, but only man-discovered, and man-formulated." [1]

The aim in discussing these concepts is to show how science has gone from the discovery of particular facts through to the highest product of such facts—their explanation in systematized knowledge which may be in the form of laws, the expression of laws in formulas, and the application of laws in principles and rules. For the purpose of revealing the fundamental processes and products of science, the activity has been analyzed and the different aspects have been examined separately. In actual scientific work the processes operate together. Thus, an investigator generally has a theory or an hypothesis before he begins looking for facts; this theory grew out of earlier knowledge, but it now serves as a guide for further observation. In other words, scientific work as we see it about us, begins with questions and is directed to the solution of problems.

The relative nature of facts. The description of the scientific method has, in the interest of simplicity, assumed that the facts from which scientific knowledge develops exist quite independent of the observer. However, since knowledge develops only through persons, it becomes important to recognize the relationship that exists between the nature of the observer and what he observes.

Different people in the same situation do not observe identical things;

[1] Wolf, A., *Essentials of scientific method,* pp. 103-104. New York: Macmillan Co., 1925.

even if they make observation of what, superficially, appears to be the same thing, the facts they report may be different. Wishes and motives enter into what is observed and how it is regarded. The child anxious for the outing notices signs of a clear day, whereas the cautious mother sees impending rain. The theory or the hypothesis held by the observer tends to color the facts that are reported. In the study of the individual who is ill the modern scientist tends to find germs or poison; primitive man saw just as clearly the influence of an unfriendly spirit. It follows that what is regarded as fact or proof is relative to our existing knowledge. The facts are not assured and final at the beginning; we try out hypotheses on the basis of facts, and select facts called for by the hypothesis. There is an interplay between the hypothesis held by the observer and the factual material that he observes and accepts; with the growth of scientific knowledge both the observed facts and the theories become stabilized and fixed.

The nature of mathematics. Mathematics is often confused with the sciences. The body of mathematical knowledge was not derived by experimentation with data of its own, but is rather the record of the experimentation made in some of the sciences. Hence, many thinkers regard mathematics as a specialized language in which the observations of the scientist are expressed. The formula for the law of falling bodies, $S = \frac{1}{2} gt^2$, for example, does no more than state precisely what was found by experimentation in the science of physics. The use of exact symbols and the careful analysis of how these may be combined and manipulated has given mathematics its great power. The processes employed in mathematics are similar to or like those employed in logic. Thus, Keyser speaks of "the epoch-making thesis established by the creators of modern logic, namely, that mathematics is included in, and, in a profound sense, may be said to be identical with, Symbolic Logic." [2] Morris R. Cohen also recognizes that "mathematics as a pure formal science is indeed identical with logic." [3]

In a certain sense of the term, the symbolic language of mathematics may in turn become a science; we may experiment with symbols to determine how they may be combined and transposed, and what processes may be legitimately performed on them. Cohen calls mathematics a science with the thought that abstractions and "relational structures" may constitute factual material that can be observed. The topic under consideration is in itself not difficult, but the use of a term in an inclusive sense by some, and with a broader meaning by others, may lead to confusion.

The new knowledge derived by means of mathematical language is

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[2] Keyser, Cassius J., *Mathematics,* p. 13. New York: Columbia University Press, 1907.

[3] Cohen, Morris R., *Nature and reason,* pp. 173-174. New York: Harcourt, Brace & Co., 1931.

gained by the process of inference, which is employed in non-mathematical languages also. Thus, if we accept the statement that only living things with a nervous system are conscious, we know without further investigating that neither plants nor chairs are aware of what happens to them. An inference based on a numerical relationship is possible after we know that the number of hairs on a person's head is always under 150,000, and that the population of a certain city is 200,000. We can now infer that each of at least 50,000 persons has exactly the same number of hairs as some other person in the city. It should be noted that truth derived by means of mathematical inference is not accepted in the field of science until it has been experimentally verified.

How science proceeds to discover relations. The culminating work of science lies in hypotheses, theories, organized knowledge, laws, and principles. How does the scientist proceed to discover these?

Most of the directions for discovering relations are safeguards against the proposal of false theories, and safeguards for testing any theories that may be suggested. The essential condition favoring the discovery of relations is the possession of accurately established facts on a central question and on others that are closely related to it. Wide critical reading, discussion with other workers, noting down for critical examination every explanation that may arise, living with problems for long periods of time, and other similar suggestions are often made. Hypotheses are generally the product of intellects that are keen and of people who are alive and vigorous in their reactions. The emphasis probably needs to be placed on such basic conditions rather than on simple rules. Provide the conditions, and the relationships will be seen. This view is supported by the fact that many discoveries were made by two or more people independently at approximately the same time.

The safeguards against forming wrong theories and for evaluating the theories suggested by others are numerous. The facts developed in chapter 1, regarding a critical and an objective attitude, are important. Theories must grow out of the basic facts, not from wishes or opinions. To establish facts, we must turn to experiences for our conclusions. It is wisely said that any suggested explanation which cannot directly or indirectly be put to the test of observation, so as to be either confirmed or confuted by it, is of no use to science.

A second safeguard is to accept the explanation that applies to the greatest number of facts. The action of the pump in drawing water from a well was at one time explained by the theory of suction. However, a second theory, that of air pressing the water upward into a vacuum, is now preferred, since it explains not only all that suction would explain but also a large number of additional facts—the exact distance the water rises,

the fact that the pressure upward is less on a mountain, and the like. The theory which explains the larger number of facts is preferred over another that has a limited application.

But the hypothesis that suction is a force might still be shown to be consistent if it could be modified by certain qualifications. To take into account its decreased action on a mountain, we might add that the force varies with its distance from the center of the earth; to take into account the fact that it does not work in a vacuum, we could add that it is a force operating only in the air. This type of qualification could be continued to any limit, and any theory could be shown true. How shall we determine which theory to accept? This has led to the safeguard that the simplest theory must be accepted when other considerations are equal.

The two tests of rival theories, that of widest applicability and that of simplicity, are together known as the law of parsimony, or Lloyd Morgan's canon. The test is probably a narrowed application of "Occam's Razor," a product of the thinking of the Middle Ages, which called for elimination of all unnecessary facts in conducting an argument.

Finally, as a safeguard in a time that speaks of "exceptions to laws," it should be emphasized that any hypothesis must take into account all the known facts in order to advance a theory. The laws of science permit of no exceptions; if some are found, the basic facts, including those that appear to be exceptional, must again be examined for a unified view that will include all.

Other safeguards in the development of theories will be found in scientific studies which employ them. It is improbable that students in an introductory course will make a great deal of conscious use of any of the principles here briefly presented, but most individuals will do clearer thinking after having had them pointed out. The chief purpose in discussing them at this point is to complete the description of the mental processes which characterize this age, and which constitute the background of the work outlined in subsequent chapters.

Summary. Science is distinguished from other fields of knowledge only by the method it pursues. The method of science covers the twofold field of ascertaining facts, and establishing relationships among facts. In the discovery of facts the method of science is that of experiment. The experimental approach varies with the problem under consideration, but employs for all investigations such common elements as the isolation of the facts to be studied, the control of conditions, the provision for repetition of the event studied, and the like. In establishing relations among facts, the method that constitutes science safeguards its conclusions by observing such principles as the law of parsimony, and by accepting no expressed relationship which does not include all known facts: scientific

laws permit of no exceptions. The relationships among facts exist in the form of hypotheses, theories, and systematized knowledge; for certain facts the relationship is expressed in laws.

Any field of knowledge that uses the experimental approach to truth is a science, irrespective of what field of inquiry it may be. Science may thus include plants and their growth, the form and sound of words, textiles, the movement of stars, or human reactions. It should be carefully observed that simply giving facts in these fields, or any other, does not constitute science. Such impartation of facts is often the reverse of science, since the truth of the facts depends not on experiment but on the authority of another person or on general impressions.

The prescientific methods of establishing facts. The significance of the scientific movement is most clearly seen when it is viewed in contrast to the method that fulfilled the same function during the centuries before the method of science was known. The prescientific method of dealing with the human problems which form the core of psychology was to judge by general impressions and on the basis of casual observation. In the intercourse of people one person would receive impressions from others, and from a large number of such impressions generalizations would appear. Usually, these generalizations would be directed to the practical problems of living; proverbs and fables give us the result of these casual observations. Their value is seen in the fact that we still need them, but they reveal the limitations of all knowledge that has not been rigidly tested and whose field of operation is not carefully prescribed.

Making complete application of the knowledge derived by non-scientific methods reveals its weaknesses. Such a proverb as "Silence is golden" is transgressed by the person who utters it. Generally another saying with a modified meaning maintains a semblance of order in the teaching offered. This crystallized knowledge of the prescientific past shows a greater interest in harmonious living than it does in carefully defined truth, which is the province of science. When it attempts to go beyond the needs of everyday adjustments into the realms of fact it becomes a counterfeit of science and a part of the superstitious lore of the race.

Not only did the casual observation which underlies prescientific thought not state the full truth, but it led to errors of thinking which magnified its own deficiencies. Since there was no opportunity for many to make even the casual observation from which conclusions were drawn, the tendency to accept the conclusions of others became fixed. Reliance on authority characterized the thinking of most enlightened people prior to the year 1600, the approximate date for the beginning of the scientific age.

This reliance on authority on the part of educated men in this period needs to be clearly comprehended, both for the insight it gives into the

civilization of a former age and as a background for understanding the meaning of science in our own age. For them the truth was known, and rational thinking served only to supply the answers to special problems. The actualities of which the present age makes so much were regarded as irrelevant. The primary concern, in any case, was the nature and the attainment of another, a supernatural world. If observed facts contradicted the products of reason based on authority, the matter was regarded lightly; conflicting facts might, by the keenest thinker, be ascribed to illusions.

This abstract discussion is illustrated by certain events of the time. One of the greatest authorities was Aristotle, whose writings permeated university instruction during the period. A student once asked his instructor whether it was true that dark spots existed on the surface of the sun. The teacher asked for time to consult Aristotle on the question; he returned with a negative answer and the information that Aristotle did not mention sun spots. Ptolemy's text in geography, written in the second century, was used in university classes. During the latter part of the period, when authority was disintegrating, a university lecturer held large classes in long debate on the new idea that human reason could not only prove what was known, but could discover new truth.

Reliance on authority will, of course, always have its place. We defer to authorities when we use the dictionary or ask a physician for advice. But whenever authority is questioned the relevant facts must again supply the answer.

Attention should finally be called to the importance attached to logical deductions as a means of arriving at the truth, during the centuries before 1600. Logic was a basic discipline for all students. The method of verbal argument as contrasted with the method of science is illustrated in the writings of Galileo (1564-1642), who was trained in both the old and the new method. He propounded the novel theory that light bodies fall as rapidly as heavy ones; this he proved experimentally by dropping objects of different weight from the leaning tower of Pisa. For modern thinkers the results of these experiments would settle the matter. Galileo, however, relied mainly on the method in common use to convince the sceptic world. His argument is quite involved, but proceeds somewhat as follows: A heavy body is in reality only a collection or combination of many light ones. Let it be assumed that the separate light bodies that make up the heavy one are near each other when they fall, and that all are of equal weight. According to the accepted view, all will fall at an equal rate. Now the several light bodies are imagined nearer and nearer together; the rate for all must remain constant, since no change has been made in the weight. Even if any two touch lightly the rate of falling must remain unchanged. Since being in contact does not change the rate, the actual combination of two small bodies can make no change. If two small bodies

fall as rapidly as one larger body, then no change in the rate of falling can result from the combination of any number of small bodies. Consequently, a light body falls as rapidly as a heavy one.

This verbal proof was answered by an argument equally involved. Because of the fact that arguments do not establish truth, the critical thinker of today asks for experimental evidence.

The growth of the scientific method. The scientific approach to questions and the scientific ideal of establishing truth was not recognized consciously as a method to be followed until it was formulated by Francis Bacon (1561-1626), a contemporary of Queen Elizabeth and Shakespeare. At this time the dialectic of Scholastic thought gave way to the impersonal search for truth by the method of science. The mediæval mind of man became in the younger generations the scientific mind of the new world.

No historic movement like that of science can, of course, have its beginning in a single individual. The searching minds of Greece contributed to the changed attitude, although their work was interrupted for more than a thousand years.

Roger Bacon (1214-1294) is profitably quoted today in his insistence that we turn from books to a real world and surrender opinions to knowledge; Occam (1270-1349) is perpetuated in the law of parsimony, which is a commonplace of scientific thinking. Many others, true scientists, could be named for the period ending about 1600, when the scientific age had its beginning.

Nor is it the sign of enlightenment to condemn an age which was not scientific. We tend to carry natural reactions that we have developed toward individuals who do not take into account the facts in an issue, to an age which showed the same characteristics. The applications of science to unworthy ends and the unwillingness of those trained in science to live its truths are also characteristic of the present age. Even though science has in our day extended its method to include almost every conceivable realm of nature, it may be discovered that from its activities, however important and useful, will not grow a full knowledge of the reality on which it works. Pearson, Mach, Ostwald, themselves scientists of the first rank, and many others, are pointing out limitations with regard to what science may be expected to do. Probably every period of civilization was as necessary to the one that succeeded it as is ours to an age of the future.

The 300 years since the introduction of the scientific method have been too short a time for it to cover more than a small fraction of the questions to which it may be expected to contribute. The method was applied first to problems that are now discussed in physics and astronomy. Modern physiology had its beginning with Harvey (1578-1657), although Vesalius (1514-1564) and other anatomists paved the way during the century be-

fore his time. Lavoisier, the founder of modern chemistry, died in 1794. Linnaeus, who established botany as a science, died during the Revolutionary War. Humboldt, the geographer, did creative work after 1850. Mendel published the studies on the law of inheritance which bear his name in 1865. Nutrition was put on a scientific basis in the years following 1915. The whole scientific movement, in spite of what we see accomplished on every hand, is relatively recent, and in many fields has no more than begun its work.

One of the recent domains for science to enter is that which is taken up in this course. The scientific movement came, in the time of men now living, to apply its approach to problems of behavior and consciousness. Before the middle of the last century the investigations of some physiologists were carried beyond organic processes to include facts on human responses. Weber (1795-1878) discovered shortly after 1830 that the relation between the intensity of stimuli that can be distinguished is roughly constant, a principle that appears to bear on important questions today. Fechner, in 1860, tried to establish a relation between the entire conscious life and the nature of stimulation, a conception much larger than that of Weber. Wundt also worked dominantly in physiological problems, but his interests went beyond these and led to his establishing at the University of Leipzig, in 1879, the first laboratory for psychology. Wundt lived and was active until 1920, and a large number of American psychologists were trained under him. Early after 1880, G. Stanley Hall (1846-1924) opened a laboratory at Johns Hopkins, and William James (1842-1910) a laboratory at Harvard; science was entrenched in a new body of problems.

During the same period English investigators penetrated into problems of psychology by working in the general field of biology. Galton published his *Inquiries into human faculties* in 1883. He also established in the University of London the Galton laboratory, which, under his direction and that of his successor, Karl Pearson, made contributions without which we could hardly conceive of the science of psychology. With these workers should be included Charles Spearman, notable for his work on the nature of intelligence. We are especially indebted to the English scientists for the application of the conception of correlation to questions of human behavior; this will be discussed in detail in a later chapter (see chapter 18).

Fifty years is a short period in the life of a science; whatever this may detract from the glories of the present must be added to the promise for the future. Cattell at Columbia—and later as editor and publisher—Jastrow at Wisconsin, Titchener at Cornell, Hall at Clark, and Wundt at Leipzig were active in the fifth and sixth decades of the science they helped to create.

Questions and Topics for Discussion

1. Trace the development of a theory in some science in which you are interested.

2. Compare the position of the text with the following statement: " . . . the dependence of thought upon language is clearly seen in many instances, there being no better illustration than that of mathematical symbolism, which is a kind of language." [4]

3. Classify leading psychologists on the basis of the method they employ in their work.

4. A scientist announces certain new facts and a theory regarding their meaning. Which would reflect on him more seriously: to disprove the facts, or the theory?

5. Distinguish between a guess and an hypothesis.

6. Does science deal with what is good and valuable or with what is true? How do we reach our conclusions regarding the desirability or the value of certain acts?

7. It is important in problems of psychology to show how a purpose comes into existence and how it modifies behavior. But it is not a part of the work of science to determine which purposes are to be preferred. Discuss.

8. Illustrate from everyday life how all at times use the method of the scientist to establish facts, and at other times disregard it. On what do we generally base our knowledge?

9. Illustrate from your own observation the explanation of common facts by wrong theories, and show why the theory proposed is not as valid as some other.

10. Examine carefully the arguments on an important question. How conclusive are the reasons presented?

11. Did arguments give the correct answers to questions in the past? Examine the early arguments on problems that have since been solved by the experimental method.

12. Compare the view expressed in the following statement with that given in the text: "To the onlooker, science is knowledge; to the worker, it is activity. Seen from the outside, it is something acquired; seen from the inside it is the process of acquisition. . . . Thus, in common usage the word has two meanings which express these opposite points of view—meanings very significantly different, though ordinarily they are synonymously interwoven and distinguishable only as varying emphases. Their contrast is that of product and process; outcome and procedure; effect and action; . . . Science is not only a great body of knowledge: it is also the activity which has produced and is producing this knowledge." [5]

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[4] Avey, Albert E., *The functions and the forms of thought,* p. 103. New York: Henry Holt & Co., 1927.

[5] Barry, Frederick, *The scientific habit of thought,* p. 10. New York: Columbia University Press, 1927.

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Part II

THE INDIVIDUAL AND THE GROUP STUDIED EXPERIMENTALLY

We have reached the stage where we realize that we cannot solve our problems by theorizing or taking thought about them. We have also reached the stage when we find we can't solve anything by appointing committees and taking votes. (*V. A. C. Henmon, in* Journal of educational research, *October, 1928, p. 193. By courtesy of the author and the publisher.*)

INTRODUCTORY STATEMENT ON BLANKS AND PLAN OF WORK

Blanks and procedure. Three different types of blanks are provided for data on the individual and the group: (1) Blanks for the original scores of the individual. These generally accompany the description of the experiment; special blanks are provided in appendix C for studies that require a large number of original scores of which, finally, the central tendency and the variability are to be found. (2) Blanks for the scores of the group. These are included in appendix C, following the blanks for the scores of the individual. Measures from each member of the experimental group are to be entered in these blanks. Each blank provides room for the scores in a number of experiments. These scores give the basis for the description of the group. (3) A blank for the personal data of each subject. Measures of the level and of the variability are entered in this blank. This blank also provides space for the position of the individual within the group in terms of quartile, decile, or percentile positions, for both the level and the variability of the performance. The blank should give the final summary of the measures of the subject in each of the experiments that deal with individual differences. This is the last blank in the volume.

Plan of work. Many of the experiments call for computations which are not explained in the discussion of the experiments. How a record is to be described is given in some detail in part 3, which should be studied in connection with the experiments. Logically this part should come first, but time and energy are saved if no mathematical concepts are introduced until there is a definite need for them on the part of the student.

The discussion or solution of certain questions and problems raised with many of the experiments is necessarily deferred until the concepts required for their solution have been presented. It may be necessary to postpone all questions dealing with correlation, for example, until a number of experiments have been performed, and until the concept has been presented.

As the course in experimental psychology measures individual differences, it is properly adapted to the differences that are discovered. Some students will profit little from detailed mathematical considerations; others, again, ask for the derivation of the Pearson formula and the use of partial correlations. Statistics as such, it is well to realize, is not psychology, but only a tool with which to describe and interpret certain

psychological data. What will promote the intellectual growth of the student depends more on the student than on the subject matter that is available.

Attention is finally called to the fact that the general plan outlined in the course makes the inclusion of other experiments readily possible; this is to be encouraged at the present state of our knowledge of what is functional in the field. The outline of the field as given in the chapter headings of part 2 can be used to orient students when new experiments are introduced. It is probably not of major importance whether the experiments begin with the first or with any of those that follow.

It is, of course, possible to perform the experiments without the stress on the differences among the members of the experimental group. Often the results obtained from other classes give a better index of the relative position of the individual than do those of the group in which the individual may be a member. It is also to be observed that conclusions not concerned with individual differences inhere in every experiment.

The experiment on the rate of writing letters is worked out rather completely in appendix A. This is to serve as a model for the detailed experiments on individual differences, and it should be consulted for the manner of describing a record completely. Generally a large number of experiments have been performed before the necessary concepts have been introduced that will enable a student to describe his performance in any one experiment completely.

It is possible that the careful description of a record, together with the reading and the discussion of problems pertaining to the experiment, will displace the detailed written report that was traditionally required on each investigation.

CHAPTER 3

Structural and Functional Characteristics of the Organism

Several of the early investigations require only a few measurements, and these are of a relatively simple kind. The aim in the first studies is to acquaint the student with his physical self; some basic facts will be revealed, and attention will be directed to the possibilities in the field.

EXPERIMENT 1.—HEIGHT AND WEIGHT

Procedure. The height is measured by standing against an upright or a wall on which a mark may be placed or to which a measuring rod has been fastened; the height of the heel of the shoe is subtracted from the total to find the correct height. Allowance must be made for the weight of heavy garments such as coats and sweaters in finding the correct weight.

Results. Enter your height and weight, and also the height-weight index to be explained in a succeeding paragraph, in the blanks below. Report these facts in the class summary blank in appendix C for the description of the experimental group; when all subjects have reported similar data, compute the group description for the blanks below.

Subject: ht..................; wt..................; ht./wt. index..................

Group mean: ht..................; wt..................; ht./wt. index..................

Group SD: ht..................; wt..................; ht./wt. index..................

Discussion and interpretation. 1. Compare yourself with the members of your group, or with the individuals whose records are given below, by finding the quartile or decile positions of your measurements. Enter these data in the personal data blank.

2. Compare the experimental group with the groups described below, in height, weight, and the height-weight index. The comparison of groups needs to be done very cautiously, since the difference found between groups is often not reliable; measuring additional people of either or both groups being compared might change the difference even to the extent of reversing

it. The discussion of the topic in chapter 19 includes methods of measuring the reliability of a difference.

3. The importance attached to height and weight as an index of development should be noted by all who deal with children. Norms have been worked out for all ages, and these should be used by parents and teachers. Books on child psychology give standards in height and weight for children from birth to maturity.

4. The general build of the body is represented by the ratio of height to weight. Such terms as slender and stocky are, for accurate description, displaced by this index. The index is found by dividing the height in inches by the weight in pounds; the soldier in our first draft who was of average height (67.7 inches) and of average weight (141.5 pounds) had a height-weight ratio of 67.7 ÷ 141.5, or .48. The index of .48 is close to the index found for men below thirty years of age; the average for women of the same age is slightly over .50. For older men and women the index tends to be larger. The index is often multiplied by 100 to remove decimals. It should also be noted that the method of computing the index varies among workers in the field.

5. The relation between general ability and height or weight is negligible in adults. Some evidence indicates that men and women of large build are favored for the more responsible positions in life.

6. The coefficient of correlation between height and weight is about .50; it is somewhat higher for men than for women.

Results of Measurements of Height and Weight

Height of College Men and Women

Height	*College Men*	*College Women*
75—75.9	1	0
74—74.9	6	0
73—73.9	8	0
72—72.9	11	0
71—71.9	28	1
70—70.9	34	1
69—69.9	30	3
68—68.9	25	4
67—67.9	15	5
66—66.9	17	9
65—65.9	11	17
64—64.9	10	20
63—63.9	7	34
62—62.9	4	20

61—61.9	3	14
60—60.9	2	12
59—59.9	0	2
58—58.9	0	1
57—57.9	0	1
56—56.9	0	1
55—55.9	0	2
54—54.9	0	1
53—53.9	0	1
52—52.9	0	0
51—51.9	0	1
Total	212	150
75th percentile	71	65.1
50th percentile	69.4	63.4
25th percentile	66.9	62.1

Height-Weight Ratio of College Men and Women

Height-Weight Ratio	*College Men*	*College Women*
68—69.9	0	1
66—67.9	0	3
64—65.9	0	3
62—63.9	2	10
60—61.9	0	11
58—59.9	7	7
56—57.9	6	11
54—55.9	19	20
52—53.9	22	24
50—51.9	31	16
48—49.9	34	21
46—47.9	40	9
44—45.9	21	6
42—43.9	17	3
40—41.9	8	4
38—39.9	3	0
36—37.9	0	1
Total	210	150
75th percentile	52.3	57.5
50th percentile	48.9	53.25
25th percentile	46.2	49.4

Weight of College Men and Women

Weight tends to increase during the middle years of life; comparisons should be made only among people of the same age. The figures here given are for college sophomeres.

Weight	*Men*	*Women*
185—189.9	1	0
180—184.9	3	0
175—179.9	3	0
170—174.9	3	0
165—169.9	5	0
160—164.9	13	1
155—159.9	17	4
150—154.9	25	1
145—149.9	19	3
140—144.9	25	7
135—139.9	26	10
130—134.9	21	14
125—129.9	19	18
120—124.9	13	18
115—119.9	1	23
110—114.9	6	17
105—109.9	1	13
100—104.9	0	12
95— 99.9	0	3
90— 94.9	0	3
85— 89.9	0	3
Total	201	150
75th percentile	153.9	131.1
50th percentile	142.7	120.3
25th percentile	132.5	106.0

Summarized Data on Large Groups

	1,000,000 Draft Recruits	*College Men Under Age 30*	*College Women*
Height	67.7 inches	68.7 inches	62.3 inches
Height SD	2.7	3.7	5.3
Weight	141.5 pounds	141.5 pounds	118.2 pounds
Weight SD	17.4	12.3	15.7

EXPERIMENT 2.—CONFORMATION OF THE HEAD

Apparatus and procedure. To determine the shape of the head, two measurements are required: (1) the length from the forehead to the back of the head; (2) the width from one side of the head to the other. Head calipers have been designed for making these measurements.

In finding the width, the ends of the calipers are applied above the ears and the instrument is moved until the tips are at the widest part of the head; this width is recorded, and then checked by repeating the measurement. For the length of the head, one tip of the calipers is placed on the forehead, between the eyebrows, and the other tip at the farthest projection of the back of the head; the measurement is checked as was done for the width.

If calipers are not available, very accurate results can be obtained by measuring the shadow of the subject's head in a semi-darkened room. The subject stands close to a wall at one end of the room, and a light is placed at the other end. Two pencils of known length are rounded at one end, and these are held against the head in the positions mentioned for the points of the calipers. The end of the shadow of each pencil on the wall is marked by an assistant. The combined length of the two pencils is subtracted from the distance between the two points on the wall to give the dimensions of the head. The dimensions are slightly magnified, particularly in a short room; this can be corrected by noting the per cent of increase that appears in the shadow of a foot ruler, and reducing the original measures by this percentage. The measurements are generally taken in centimeters.

Results. Enter the measurements for length and width in the blanks below. The shape of the head is described in terms of a ratio known as the *cephalic index;* to find this, the width is multiplied by 100 to remove decimals, and divided by the length. For example, a head that is 18.4 cm. wide and 24.3 cm. long has a cephalic index of $\frac{100 \times 18.4}{24.3}$, or 75.7. Include the measures in the blanks for the class summary and the personal data blank.

Subject: width............; length............; cephalic index............

Group mean: width............; length............; cephalic index............

Group SD: width............; length............; cephalic index............

Discussion and interpretation. 1. The shape of the head varies from round to long; the term "long," it should be noted, does not refer to the

distance from the chin upward, but to the distance from the forehead to the back of the head.

2. Heads with a cephalic index of 80 or above are classed as round, those below 75 as long, and those between these figures as average. The technical names for the different shapes are, respectively, brachycephalic, dolichocephalic, and mesocephalic. A range in cephalic index from approximately 62 to 98 has been found in normal persons; pathological cases extend this range about 8 points at each end.

Small positive correlations favorable to the large and the round have been found; they are possibly negligible. The gifted children studied by Terman have a cephalic index that ranges from 71 to 92 for boys, and from 71 to 89 for girls; the mean for both sexes is approximately 80; it should be noted, however, that the cephalic index decreases as a child matures.

The cephalic index measure has extensive use in the determination of sex and race differences, and in tracing the growth of children. The Oriental head tends to be round; that of the negro, long; men have longer heads than women; the head becomes longer as children develop.

Results of Measurements of Cephalic Index

Cephalic Index	*College Men*	*College Women*
88—89.9	1	0
86—87.9	2	1
84—85.9	6	5
82—83.9	8	10
80—81.9	22	14
78—79.9	31	19
76—77.9	36	18
74—75.9	24	16
72—73.9	16	15
70—71.9	8	11
68—69.9	2	8
66—67.9	1	3
64—65.9	1	2
62—63.9	0	1
	158	123
75th percentile	80.0	80.0
50th percentile	77.5	76.6
25th percentile	75.0	72.8

EXPERIMENT 3.—MUSCULAR STRENGTH

Problem. To determine the strength of the subject's grip.

Materials. Hand dynamometer for subject; watch for experimenter.

Procedure. The dynamometer should be adjusted so that the pressure on the stirrup will be exerted by that portion of the fingers between the first and second joints. The instrument is raised to the level of the shoulder and the maximum pressure is exerted as it is rapidly lowered. Thirty trials are required with the preferred hand, with a rest period of 15 seconds between trials.

Results. Enter the scores of the 30 trials in the blank in appendix C. Describe your record in terms of mean, standard deviation, and coefficient of variation. Enter these results in the blank for the class summary, and describe the experimental group as you did your own performance. Give the description of your own record, as well as that of the group, in the blanks below:

Subject: M..............................; SD..............................; V..............................

Group: M..............................; SD..............................; V..............................

Discussion and interpretation. 1. From the class record or from the data given below, find your position with regard to muscular strength, and report this in the personal data blank.

2. Note whether any peculiar features of the records, such as an abrupt change in the scores, are explained by observations of the subjects.

3. Report on evidences of fatigue in the record. A graphical representation will reveal any trend in the record more clearly.

In adults the correlation between strength of grip and intelligence is negligible. In children below 14 years of age strength is found to correlate about .70 with age; limited data show that children with high intelligence have a stronger grip than the average. The grip of the left hand is roughly 10% less than that of the right. Males are distinctly stronger at all ages than females.

RESULTS OF MEASUREMENTS OF STRENGTH OF GRIP

Kilograms	*Men*	*Women*
75—79.9	1	0
70—74.9	2	0
65—69.9	8	0
60—64.9	37	0
55—59.9	42	0
50—54.9	60	0
45—49.9	29	2

40—44.9	26	3
35—39.9	10	22
30—34.9	2	42
25—29.9	0	37
20—24.9	0	16
15—19.9	0	4
	217	126
75th percentile	59.3	34.5
50th percentile	53.5	30.7
25th percentile	47.8	26.6

Supplementary experiments. A large number of interesting studies are possible in the field of muscular strength. (1) The preferred and the non-preferred hand may be compared. (2) The course of fatigue may be studied by continuing the experiment and reducing the length of the interval between the trials. (3) The study of strength may be extended to include the arm, the back, and other muscles.

EXPERIMENT 4.—RECOVERY FROM WORK

Problem. To determine how rapidly a subject recovers from physical exercise.

Materials. Watch for experimenter.

Procedure. With the subject standing, the pulse is counted accurately for one minute. Students should practice counting the pulse outside of the laboratory; the beat can be felt distinctly on the wrist at the base of the thumb. For the experiment the count should be repeated to assure accuracy. A tack or a paper clip held in position over the artery on the wrist by a rubber band, gives a visual indication of the pulse and is clearer to most experimenters.

After the pulse rate has been determined, the subject goes through the motion of walking by lifting the feet alternately half way to the height of the opposite knee; 45 steps are to be taken in 15 seconds. The experimenter indicates the rate by counting or with a metronome.

Exactly 30 seconds after the exercise, the pulse is again counted; a second count is made at the end of one minute, and this is repeated at intervals of one minute until the pulse is again normal. The counting in each case is done for only 20 seconds, and the number multiplied by 3 for the rate in a minute.

Results and interpretation. Enter the results in the blank below. A

recovery in 30 seconds is excellent, in 1 minute good, in 2 minutes fair, and in 3 minutes poor.

Normal pulse rate........................... Rate 30 seconds after exercise......................; one minute after exercise......................; two minutes after exercise..........................; three minutes after exercise......................... Time for recovery.........................

CHAPTER 4

Elementary Motor Reactions and Rate of Response

Introduction. The systematic investigation of human reactions may begin with sensory processes for the study of the conscious life, or with simple movements, or motor responses, for the study of behavior. It should be realized that in each case only an aspect of the total response is investigated. The term "motor," for example, is not to be considered a separate factor appearing in a few types of responses, such as mechanical and athletic activities; intellectual, sensory, and emotional aspects are present in many responses that would normally be described in terms of movements.

The simplest movement is the reflex: the contracting of the pupil of the eye, sneezing, the knee jerk, and many others. Reflexes are profitably studied to show their dependence on the strength of the initiating stimulus, their change with fatigue, their modifiability, and for many other facts. Human reflexes are, however, so easily modified by conditioning and so obscured by other responses that simple laboratory studies reveal little of their exact nature; they should be observed in their integrated setting in the total response of the organism. The reflex in its simple form is a relatively small section of the total motor nature of the individual, and we profitably begin our inquiry with larger aspects of the field.

Recent investigations in the motor field reveal more problems than answers. We do not know whether motor skill at one age can be predicted from skill at an earlier age, whether the various motor skills are differentiated at certain age levels, whether the maximal level revealed in a test is retained by an individual when he employs the same skill in an industrial operation, or whether there are certain basic capacities underlying all motor skill. The main contribution of scientific investigation in some fields has been to show the incorrectness of popular views on the questions involved.

A wide range of topics from the motor field have been taken into the laboratory; important studies have been made on such topics as the effect of practice on motor ability, the rôle of motivation on improvement and on measures of individual differences, the nature of the inhibitory process

in reflex acts and other movements, and on the course of fatigue in motor responses. While many questions have been uncovered in recent research, there has also accumulated a substantial background of information upon which more detailed knowledge can be built. We know, for example, that no "general motor ability" exists as was formerly assumed, that specificity of skills involving the coördination of the finer muscles is the rule, and that tests will predict with some measure of accuracy certain later abilities of the individual.

A number of approaches to the problem of motor responses have been made. Some studies have attempted to find the significance of height and weight and of the strength and coördination of groups of large muscles in different activities, such as athletic skills. Other studies have been concerned with skills involving small and precise movements of muscle groups, which appear to differ greatly from the grosser coördinations. Still another approach has been the analysis of differences in complex skills into elements of speed, accuracy, and strength. Tests for measuring these elements, such as tapping, reaction time, steadiness, and strength, have been arbitrarily classified as "simple" motor tests; those involving discrimination and coördination of greater degree and complexity, such as serial reaction time and pursuit tests for fine coödinations, are designated as "complex." The experiments to be presented will center about the simpler type of response: (1) the rate at which movements are made and the time required to react to a stimulus; (2) the accuracy with which movements are made; and (3) the steadiness of the motor response.

The study of these simple motor responses has in the past had wide application in determining the conditions that affect behavior. The applications remain practical and far-reaching for the individual in their relation to the problems of life. The study of motor reactions will remain an important topic in the study of psychology.

EXPERIMENT 5.—REACTION TIME FOR TOUCH, VISUAL, AND AUDITORY STIMULATION

Problem. To determine how rapidly the hand moves in response to a touch stimulus, a visual stimulus, and a sound.

Apparatus. Determining the time of reaction is an old experiment in psychology, and several forms of apparatus have been developed for making the necessary measurements. Either of two instruments may be used in the present experiment: (1) the Dunlap chronoscope; or (2) an electric impulse counter.

The Dunlap chronoscope consists essentially of an induction motor which runs at a uniform rate. Students should note carefully the con-

struction that makes possible the measurement of time intervals of a thousandth of a second. A hand similar to that of a clock is attached to the frame of the motor in such a manner that it can be magnetically attached to or released from the turning shaft. The pressure on the key given by *E* attaches the hand and also gives the signal to *S* to remove his finger from another key; the removal of the finger stops the turning of the hand. The time interval between the giving of the stimulus and the response is thus indicated by the number of degrees through which the hand has turned.

The turns of the hand need to be translated into seconds. On a 60-cycle current the hand makes 12 complete rotations each second. Each rotation is, accordingly, 1/12 of a second. Since the dial is divided into 100 parts. each part represents 1/1200 of a second. It is customary to translate the units of time into thousandths of a second. Thus, a turn of the hand around 175 spaces on the dial represents 175/1200, or .146, of a second. Instead of writing the result as a decimal, the letter sigma (σ) is used to denote thousandths; thus, .146 of a second is written 146σ. It should be noted that multiplying the number of spaces traversed by the dial by .83 will change the reading into sigma.

The electric impulse counter is a simpler device which counts the cycles of an alternating current. When connected into a proper circuit, the pressure of a key by *E* starts the counter and also gives the signal to *S* to release his key. The release of the key by *S* stops the counter. The time that elapses before *S* releases the key is, accordingly, represented by the number of spaces that the hand moves on the counter. Since each cycle of the electric current moves the hand two spaces, the record on the timer is readily translated into seconds. For a 60-cycle current the number of spaces traversed by the hand on the timer is divided by 120 to give seconds. Thus, 16 spaces are equal to 16 ÷ 120, or .133 of a second, or 133 sigma.

Procedure for touch. Five preliminary trials should be made before the final record is taken. *S* withdraws the finger which holds down a key when he feels the touch stimulus given by *E*. Many methods are used for giving a touch stimulus at the moment that the chronoscope is started; a simple method is for *S* to place a finger of his left hand under the key to be pressed by *E*, in such a way that the pressure of the key will give the proper stimulus. More refined methods are used for accurate work.

E should give his attention to the movement of the hand, not to the stimulation. For the final record 100 trials should be taken. Throw out those records for which *S* or *E* reports an error, but retain all which were taken under prescribed conditions.

Procedure for sound. The procedure is identical with that for touch, with the exception that *S* now responds to a sound stimulus. The sound

made by the chronoscope when it begins to move is often taken as the stimulus for *S*.

Procedure for visual stimulus. The procedure already described is followed, with the exception that *S* now reacts to a visual stimulus. It becomes necessary for *S* to be in a room to which the sound of the timer will not penetrate; an electric light is generally connected with the key operated by *E* so that *S* receives a light signal at the instant that *E* starts the timer.

Results. Record the results for each sense organ in the blanks provided in appendix C. Complete the calculations for level and variability, as shown in appendix A (experiment on the rate of writing letters). Enter the results for the individual and the group in the blanks below.

	Touch	*Sound*	*Vision*
Subject mean	....	....	....
Subject SD	....	....	....
Group mean	....	....	....
Group SD	....	....	....

Enter the results in the personal data blank, and find your relative position in the experimental group.

Interpretation and questions. 1. Read chapter 9, "Cattell's experiments in the measurement of reaction time," in Garrett's *Great experiments in psychology*.

2. Do people who react rapidly to touch stimulation also react rapidly to sound? (The correlation method described in chapter 18 should be used to answer all questions on relationship between the scores in different activities.) Find other intercorrelations.

3. Examine the variability of the class in the different reaction times taken. Are people who are variable in one reaction also variable in others?

4. Attending to the stimulus instead of to the movement that is to be made increases the time required for the reaction. How may this fact introduce constant errors into the results? What effect will this fact have on the variability of the scores?

5. Where, in life, does the fact that touch is more rapid than vision play a part?

6. Is there evidence of learning in the experiment? of fatigue?

7. How can we determine scientifically whether the speed of reaction is related to success in an activity such as typing?

8. Check the measures for reliability.

9. Should the coefficient of variation be used instead of the SD as the measure of variability for the reaction time? Discuss.

10. It has been shown that the particular group of muscles employed in the test does not affect the ranking of the individual in the group. Suggest an experiment to investigate this.

11. Expecting a stimulus shortens the time of response, and a choice between possible reactions lengthens it. Suggest other problems on which the experiment in reaction time might throw light.

12. The rate of performance in complex behavior is not as consistent as in simple reactions. Plan an experiment to prove this.

Results of Measurements on Reaction Time

College Women (108 Subjects)

	Touch		*Sound*		*Vision*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
75th percentile	.110	3.2	.125	2.8	.131	4.1
50th percentile	.130	4.3	.150	3.4	.163	5.1
25th percentile	.143	5.1	.167	4.8	.170	5.9

General Studies Reported in the Experimental Literature

	Touch	*Sound*	*Vision*
Median of 14...	.141	.148	.188
Range	.117-.182	.120-.185	.151-.225

EXPERIMENT 6.—RATE OF TAPPING

Part A

Problem. To find out how many times the subject can tap a pencil in 15 seconds.

Materials. Soft pencils and cross section paper for subjects; watch for experimenter.

Procedure. At a signal from the experimenter, given after a suitable warning, the subject taps as rapidly as possible on the cross section paper. The dots should be confined to an area of about two square inches, but each should be distinctly visible. The movement of the hand should be made at the wrist joint, not at the elbow or finger. The tapping is continued for 15 seconds, when the signal to stop is given. After each trial, count the dots and enter the number in the proper blank. Thirty or more trials should be taken, with a rest period of two minutes between trials.

Results. Enter the original records in the blank in appendix C, and complete the description of your performance as shown for the record on letter writing. Report your mean and standard deviation for the class

summary blank, and describe the group performance. Give below the required information about your record and also that of the group.

Subject: mean........................; SD........................; V........................

Group: mean........................; SD........................; V........................

Interpretation and questions. 1. Find the time required to make one tap by dividing 15 seconds by the average number of taps made in the trials.

2. Calculate the coefficient of correlation between the scores in this experiment and those in other experiments measuring speed. Is rate of movement a general or a specific capacity?

3. Is the variability of the performance, as shown in different time experiments, a general trait? How is the answer determined scientifically?

Results of Measurements on Tapping

Score	*f*
120—124.9	1
115—119.9	3
110—114.9	4
105—109.9	15
100—104.9	23
95— 99.9	18
90— 94.9	12
85— 89.9	7
80— 84.9	2
Total	85
75th percentile	105.6
50th percentile	100.8
25th percentile	95.1

Coefficient of Variation

	f
0— 1.9	7
2— 3.9	17
4— 5.9	22
6— 7.9	18
8— 9.9	16
10—11.9	5
Total	85
75th percentile	3.7
50th percentile	5.7
25th percentile	6.0

Part B

Problem. Special apparatus has been designed for determining the rate of tapping; this makes unnecessary the tedious counting of dots that was required in part A, and it attempts to control other variables.

Apparatus. Two telegraph keys, or a tapping board and stylus, connected in a circuit, with a counter and a control key for *E*. Seconds timer.

Procedure. The tapping board and the two telegraph keys make it possible to have the tapping done alternately on two plates. The object of this is to control, in part, the distance that the subject moves the hand in tapping.

At a signal from the experimenter, the subject taps as rapidly as possible for 15 seconds. The wrist movement is to be used as in the previous experiment. The experimenter should make the connection with his key at the beginning of the tapping period, and break it at the end, so that the tapping periods will be exactly 15 seconds in length. The score indicated on the electric counter should be recorded after each period. A rest period of 45 seconds is given between trials.

Results. Treat the results in the manner described for part A, and enter the required data in the blanks below.

Subject: mean..........................; SD..........................; V..........................

Group: mean..........................; SD..........................; V..........................

Discussion and interpretation. 1. Find the coefficient of correlation between the tapping rate in part A and part B. What does this indicate about the relationship in the capacities employed?

2. The rate of tapping increases with age to maturity. A rate of 45 for a period of 15 seconds has been found for 8-year old children. The average for adults is over twice that number.

3. Speed in a complex performance is not closely related to speed in a simple component of the complex act. How could this matter be investigated?

4. There is no general speed factor for the right hand. Indicate how this could be investigated.

5. Examine the records for both parts of the experiment for evidence of fatigue or learning.

6. The world's record for speed in typing has almost doubled in the past 20 years. Some investigations indicate that pianists have a higher rate than the general population. What does this indicate about the possibility of increasing the speed of response by means of training?

Results of Measurements on Stylus Tapping

	Level	*V*
75th percentile	103	2.4
50th percentile	92	3.7
25th percentile	82	5.1

EXPERIMENT 7.—RATE OF WRITING LETTERS

Problem. To determine how many letters of the alphabet the subject can write in 30 seconds.

Materials. Pencil and paper for subject; watch for experimenter.

Procedure. At a signal from the experimenter the subject writes the letters of the alphabet in order as rapidly as possible; no dot is to be placed over *i* or *j;* no cross on *t* or *x;* the letters should be legible. After completing the 26 letters, the subject repeats the process until time is called after 30 seconds. Thirty or more trials should be made, with a rest period of 30 seconds between trials.

Results. The original scores are entered in the blank in appendix C. Appendix A gives a description of a subject's record in full. The average is also entered in the blank for the class summary. The required data on the subject and the group are to be entered in the blanks below. Record the measures for average and variability in the personal data blank, with your position in the group.

Subject: mean........................; SD........................; V........................

Group: mean........................; SD........................; V........................

Discussion and interpretation. 1. Is the average of the 30 trials reliable? If not, continue the test until a reliable result has been found.

2. Is there evidence of learning in the task? How would this be shown? What effect would it have on the reliability of the average?

3. Find the SD and its reliability. If necessary, continue the experiment until a reliable SD has been found.

4. Use the data from the class on tapping and on letter writing, and determine whether people who tap rapidly also write rapidly.

5. Use the scores in letter writing and in any other experiment on rate of response, and determine whether people who are variable in their rate of writing letters are also variable in the other task. Use the standard deviation as the measure of variability.

Results of Measurements on Letter Writing

Scores	*f*
84—85.9	2
82—83.9	6
80—81.9	7
78—79.9	9
76—77.9	12
74—75.9	14
72—73.9	17
70—71.9	22
68—69.9	14
66—67.9	10
64—65.9	10
62—63.9	8
60—61.9	4
58—59.9	1
56—57.9	2
Total	138

75th percentile	76.3
50th percentile	71.8
25th percentile	67.9

SD	*f*
0— .9	2
1— 1.9	8
2— 2.9	20
3— 3.9	18
4— 4.9	36
5— 5.9	36
6— 6.9	18
7— 7.9	12
8— 8.9	8
9— 9.9	2
10—10.9	1
Total	161

75th percentile	3.4
50th percentile	4.1
25th percentile	7.0

EXPERIMENT 8.—MEASUREMENT OF MUSCULAR CONTROL

Problem. The experiment has for its object the measurement of the control in the muscles of the hand and arm.

Apparatus. Several types of apparatus have been developed to measure motor control. The tracing board test requires the tracing of a stylus between two metal strips. In another test a metal plate with nine holes of different sizes is placed before the subject and he is required to hold a metal stylus in a prescribed hole without touching the sides. A modification of this, developed by Dr. Heinlein, has the advantage of being adjustable to the height of the subject and also of giving a warning light whenever the stylus touches the metal. Whichever type of apparatus is used, it is placed in an electric circuit, with a key by means of which *E* can open and close the circuit. A stop watch will be needed by *E*. A telegraph sounder is required for the tracing board and an electric counter for both forms of the perforated plate.

Procedure for tracing board. The board is placed on a table before *S*, so that his hand moves toward the body when he traces along the narrow path with the metal stylus. The sounder gives a signal when the stylus touches a metal plate; the distance that the subject traces along the path before touching the side is the score. After several preliminary trials, the record for 30 trials is entered in the blanks in appendix C. The time for tracing the full length of the strips should be kept between 8 and 10 seconds.

Procedure for the perforated plate and disc. The disc is adjusted to the height of the subject's elbow; the slant of the disc is such that the stylus when held in a hole makes a right angle with the plane of the disc. The hole to be used is turned to the top position. The subject stands before the disc with his arm free of the body, and at a sign from the experimenter inserts with the preferred hand the point of the stylus in the middle hole. The stylus is held in position until the end of the trial. After 3 seconds *E* closes the circuit, and any contacts that the stylus now makes are automatically counted. Fifteen seconds after the circuit was closed it is again opened, and *S* assumes a resting position for 45 seconds. Thirty trials are required. The subject should notice the warning light and adjust the stylus as soon as the light is seen.

If the metal plate is used in place of the disc, it should be placed on the table before the subject and the procedure described for the disc should be followed. The arm should not touch the body nor the table.

Results. The mean and the SD of the scores are reported for the class summary and personal data blanks; each subject should indicate his position in the experimental group. The required information is to be entered in the blanks below.

	Tracing Board		*Plate*		*Disc*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Subject	....	....	....	....	....	....
Group	....	....	....	....	....	....

Discussion and interpretation. The methods of scoring the different tests vary widely; some employ a counter with the tracing board and use the number of contacts made in tracing the full length of the metal strips as the subject's score. For the perforated plate and disc the contacts made in all nine holes in sequence are used. Other methods will be found in the experimental literature.

Find intercorrelations for the experiments in this section and also for any other experiments that appear to be related.

Results of Measurements on Steadiness

	Tracing Board	*Perforated Plate*	*Perforated Disc*
75th percentile	5.2 in.	5.1	6.0
50th percentile	6.4 in.	6.2	7.1
25th percentile	7.5 in.	7.3	8.6

Supplementary experiments. A wide range of experiments are possible with the apparatus described. The non-preferred hand may be studied; learning appears to take place, and the course of this can be traced; fatigue can be objectively studied by prolonging the time that the stylus is held in a hole; the scores for different holes may be statistically analyzed.

EXPERIMENT 9.—PRECISION OF MOVEMENT

Problem. To determine how accurately a prescribed movement is executed.

Materials. Before the meeting of the class each student should prepare, on two sheets of unruled paper, 30 lines each exactly 10 inches long. The lines should be drawn with a pen that has a fine point. They are to be spaced about ½ inch apart. On each of these 30 lines very light cross lines are drawn 1 inch apart. The subjects should also bring a long pencil with a hard lead that is well sharpened. *E* needs a watch, or preferably a metronome with a bell.

Procedure. The task will be to trace each of the lines with the pencil. Unless conditions are kept uniform the scores will be meaningless. The pencil should be grasped firmly 5 inches from the point, and held at an angle of 60 degrees with the paper, which is placed on a table before the

subject. The tracing must be done at a uniform rate. The experimenter counts at the rate of one per second, and the subject traces at the same time one inch for each count. The subject begins tracing at the starting signal; when *E* says "one" he should be at the first cross line, for "two" at the second, and so on to "ten," when the subject should have completed the tracing of the line. Several practice trials with an unsharpened pencil should precede the experiment proper. Thirty trials constitute the experiment; a rest period of 30 seconds is given between trials.

While performing the experiment the subject should be seated comfortably at a table. The arm needs to be free. The tracing is to be done by drawing the pencil toward the body.

Results. An error is counted whenever the pencil leaves the line. To constitute an error, the white paper should be visible between the base line in ink and the tracing in pencil. In case the pencil leaves the line for ½ inch or more at any point, the number of errors is increased to make up for the distance not traced. Compute this correction by noting that if the pencil traced the line for only 9 inches, the number of errors must be increased by 1/9; if the tracing was done only on 8 inches the correction must be 2/8; and so on for other distances.

Enter the original scores in the blank in appendix C, and report the mean and the standard deviation for the class summary and the personal data blanks. Give the required information in the following blanks:

Subject: mean.........................; SD.........................; V.........................

Group: mean.........................; SD.........................; V.........................

Discussion and interpretation. 1. Find the intercorrelation between the score in precision and other motor measurements. Do the coefficients found indicate that there is a general motor ability or specific motor abilities?

RESULTS OF MEASUREMENTS ON PRECISION

	Mean	*SD*
75th percentile	4.1	2.0
50th percentile	5.1	3.2
25th percentile	6.2	4.1

CHAPTER 5

The Arousing of Reactions: Stimulation and Sensory Processes

Human reactions occur as responses to stimulation. More than a dozen avenues of stimulation have been discovered in place of the traditional five. This chapter will deal with questions on: (1) the arousing of reactions by methods other than that of sensory stimulation; (2) the description of sense organs and their operation; (3) the qualitative responses from different sense organs; and (4) the quantitative relationship between the nature of the stimulus and the response.

Section A.—Reactions the Result of Stimulation

EXPERIMENT 10.—POSSIBILITY OF AROUSING REACTIONS WITHOUT THE STIMULATION OF A SENSE ORGAN

Part A.—Results from Chance Occurrence

Introduction. The view that reactions are aroused only by definite stimulation has not always been accepted, and it is questioned today by many who have not examined the facts carefully. Human behavior appears too complex and too far removed from stimuli to be readily related to such stimulation. It is customary to speak of certain ideas or certain facts (both of which are reactions) as being the result of "intuition," or as "just occurring," without considering that a stimulation of some kind must have been operative. Premonitions and dreams are more often examined in their relation to future events than to their origin. Most events of the type here mentioned do not lend themselves to experimental study, since the conditions required for their occurrence are not readily isolated or placed under the control of the experimenter. It is even held by some that any attempt to study the phenomena under experimental conditions interferes with certain processes, and hence any conclusions are invalid. Before accepting such condemnation to perpetual ignorance, it will be enlightening to examine objectively the phenomena in a small section of the total field.

Problem. To determine whether thinking of a number on the part of experimenters will influence the responses of subjects.

Materials. Pencils and paper for the subjects and experimenters. Cards ¼ inch square or larger, numbered from 1 through 10. A small box in which the numbered cards can be readily mixed is convenient. Two sets of cards, one of which is being shuffled while the other is in use, will assure complete mixing of the numbers and lead to more uniform results.

Procedure. From one to four students act as experimenters; the remainder of the class are subjects. The experimenters should sit around a table in the rear of the room. A number is drawn from the box and each experimenter looks at it. One now gives the signal "Ready," and all *E*'s think of the number drawn. The *E*'s wait about 6 seconds, and then one gives the signal for the subjects to write; at this time—or before, in case a subject prefers—each subject writes the number that occurred most strongly to him.

One of the *E*'s gives the correct number, and the subjects check their answers. The card is replaced, and after thorough mixing the procedure is repeated. Enough trials should be made so that the total from the group is at least 1000.

Results. At the close of the experiment each subject reports the number of right responses, and the total of the class is found. It may be advisable to secure the data with different groups acting as experimenters.

Discussion and interpretation. Out of 10 numbers written by the subjects, 1 will be correct by chance. A concrete case will show how the results are to be interpreted.

In a class of 35 subjects 30 trials were made. The total number of correct responses reported by the subjects was 104.

Number of trials........................	$30 \times 35 = 1050$
Number correct by chance.................	$1/10$ of $1080 = 108$
Part that correct answers are of those that chance would give....................	$\frac{104}{108} = .963$

Accordingly, the experiment gives 96.3% of the number of answers that chance alone would account for. The results are negative. Evaluate the results of the experiment.

Part B.—Results Affected by Obscure Factors

The experiment is repeated, with the procedure modified as follows: From 1 to 4 subjects act as experimenters, and the members of the class are subjects. The *E*'s should gather in the rear of the room. One of the *E*'s takes any number from 1 to 10 inclusive that occurs to him, and com-

municates it quietly to the other *E*'s. The signal "Ready" is given, and all experimenters think of the number selected. After about 6 seconds the signal "Write" is given, and each subject writes the number that occurred most strongly to him. One of the *E*'s now gives the correct number, and the subjects check the answer as right or wrong. *E* then takes a second number, and the process is repeated until the total number of trials from the entire class is at least 1000. The procedure must be followed without any modification.

Results. Report the class results in the following blanks.

	Part A	*Part B*
Total number of trials........	....	....
Number correct by chance.....	....	....
Per cent correct above chance..	....	....

Discussion and interpretation. The results when the second method is used are generally about 3 times chance. The habit of taking certain numbers in succession is possibly the same in subjects and experimenters.

Section B.—Experiments in Sensations: Limitations and Methods

The possibility of measuring conscious reactions. Each of two persons has a pound weight resting on his hand, and each is aware of the pressure. Is the consciousness of pressure experienced by one equal to or exactly like that experienced by the other? The question cannot be answered. If one of the two is a child and the other an adult, the first may sense the pressure as extremely strong and the second as weak. If the weights are adjusted so that both describe their conscious experiences in the same words, we cannot say that the experiences are alike. What two people may describe as slight pressure may be quite different.

What is said here with reference to measuring reactions to pressure applies to the conscious reactions aroused through every other sense organ. The pain described in the same words by two people is probably unlike. What one calls an awareness of deep blue may be something different from the awareness of another, even though he uses the same descriptive words. When two people describe their reactions to a sound stimulus as being moderately loud, the two conscious reactions are thereby not known to be alike. The facts here stated limit the rigid scientific investigation of conscious reactions. So evident is the difficulty that many people in the history of the science have denied the possibility of making any measurement at all in the field. Such individuals have conceded qualitative

studies that would distinguish between sweet and bitter, between blue and purple, but have not considered possible any measurement in quantity.

The field of possible measurement. It is, however, possible to compare accurately the conscious reactions that different individuals make to stimuli at several points in the range of stimulation. One of these points is the *weakest stimulus* that will arouse a reaction. This may be investigated for any sense organ. What is the weakest sound that can be heard? This is roughly measured in terms of the distance from the ear that a particular watch can be heard. With a constant intensity of sound, the experimenter can compare any number of persons in the intensity that will just arouse a reaction. The same fact is true of other senses. What is the smallest amount of color that will arouse a response? What is the smallest amount of salt, of pressure, of pain, of cold, of sweet that will bring about a reaction in the human organism? At this point any number of people can be compared, with complete assurance that the results will be scientifically valid. It is also possible at this point to compare a person from day to day or to make a composite record that will express the nature of the individual with scientific precision. The results are given in terms of strength of the stimulus—a light of so many candle power at a given distance, a pressure of so many grams, and the like.

The technical name for this field of investigation is the *lower threshold* for the particular sense organ being studied. Much of the early experimental work in psychology was on the problem of the lower threshold in the different sensory fields.

A second point at which two people may be compared is at the *upper threshold.* Such investigation seeks to determine at what degree of stimulation the particular sense organ is roused to its maximum reaction. How much light must fall on the page before the addition of more light will not be noticed? How bitter must a solution be before the intensifying of the bitter substance will make no change in the reaction? It is possible to investigate this problem for several sense organs. Comparatively little work, however, has been done in this field because the results are generally less significant than those for the lower threshold, and also because the maximum stimulation may injure the organism during the period of experimentation.

A third field of investigation in which rigid scientific methods can be observed is the measurement of differences in the stimulation required to produce a difference in reaction at any point in the field of stimulation. For example: A particular shade of blue is given. How much blue must be added or subtracted before a difference will be observed? ("Observing a difference" puts in a personal way what is often better thought of, impersonally, as "producing a different reaction.") A fork with known vibration rate is sounded. How many more or fewer vibrations must come

from a second fork before the reactions from the two will be sensed as different? Technically, this type of investigation is known as finding the *difference threshold.* It is used extensively for some of the sense organs, especially hearing, and it is of large importance in the study of human behavior. As will be indicated later, different thresholds play an important part in the adjustments that are possible for an individual. A person who cannot distinguish between the sound of a fork vibrating 256 times a second and another at 266 lacks the capacity for success in certain musical work. The subject who required the largest addition of red to change a given tint did not respond with the usual enthusiasm to delicate colors in dress material and inclined to prefer strong contrasts. The finest appreciation of delicate flavors will probably come to those who have a low threshold for taste and odor and a small difference threshold. Many fruitful topics for investigation are indicated by a survey of the field of difference thresholds and their relation to adequate adjustments.

Quantitative studies can also enter a fourth field, that of determining the strength of two stimuli that appear equivalent, and a fifth, that of determining differences in stimuli that are sensed as equivalent. The present course will not introduce these concepts.

Methods of measuring thresholds accurately. The foregoing paragraphs on the possibilities of measuring conscious reactions restrict such investigations to a number of limited fields. At several points only can these reactions be accurately measured, and then the results are stated quantitatively in terms of the stimulus. In this limited field great care must be exercised if reliable results are to be found. In the history of the science three standard methods for accurately determining thresholds grew out of the labors of experimenters. These have a much larger field of application than the study of thresholds, and it is worth knowing them as general methods of accurately establishing facts.

The method of continuous changes or variation. This method appears to be the natural one for students to adopt in attempting to measure the lower threshold. Suppose that the problem is to find how far from the ear the ticking of a watch can be heard. The subject may give directions to remove it farther and then to bring it nearer until a position has been found in which it can just be heard. This is the method of continuous variation. Measurements obtained by it are not as reliable as those obtained by either of the other two methods. Not only do the results lack reliability, but it is very difficult to describe the procedure so that another can perform the experiment with identical conditions prevailing. It is important, for example, to know whether the last change in the position of the watch was away from or toward the ear of the subject, at what rate the irregular changes were made, and how fast the watch was moved. These facts are controlled in other methods.

The method of minimal changes. In this method the watch is brought near enough to the subject so that it is clearly heard. It is now moved at an even rate farther and farther from the subject, until a point is reached where it is no longer heard. This distance is recorded, and a second trial is made by beginning at some point unmistakably beyond the range of the subject and moving the watch closer until it is heard; this distance is again made a part of the record. The process is repeated at least 5 times —more trials are usually required for accurate results. A separate average is found for the ascending and the descending records. For the most accurate work the results are used in this original form; generally the two scores are averaged to find a single figure for the threshold.

The advantage of this method over that of continuous variation should be observed. Not only are the results more accurate, but it is possible to describe the procedure so that the experiment can be performed by another person. Such standardization of the conditions under which an experiment is performed is essential if the results from different individuals are to be comparable.

The method of minimal changes, as the method here described is called, can also be used to find the difference threshold. Suppose the difference threshold for hearing is to be determined. A fork of, say, 256 vibrations is sounded, and then another that can be clearly distinguished from it. Now small or minimal changes are made in the differences between the two forks until the forks sound alike to the subject. The process is continued by beginning with a difference that is distinctly too small to be recognized. The trials for both the increasing and the decreasing difference must be repeated a number of times for a final result. It is necessary in an experiment of this kind occasionally to strike the same fork twice in succession, in order to make sure that discrimination in pitch is actually being measured. Sets of tuning forks for an experiment of this type are in common use in laboratory work.

The method of right and wrong answers. The method to be described is sometimes called the method of right and wrong cases and also, since the stimuli are not changed during any step in the testing, the method of constant stimuli. It is probably the most accurate of the three methods of investigation. In using it, say, for finding the difference threshold for discrimination in pitch, the approximate difference is first crudely established by any method. Suppose this is found to be 5 vibrations. Now two forks with this difference are used to determine definitely whether this is the difference that the subject can actually recognize. The order of striking the two forks, whether the higher first or second, is left to chance. After the two forks have been sounded, the subject expresses himself with reference to the second sound. It is higher or lower than the first, or it is equal to the first. The experiment may be simplified by never permitting the

answer that one is equal to the other—the subject must give one as higher, even if the answer is a guess.

If from 20 trials only half are right, the subject has done no better than guess; if all are right—or nearly all—he can probably distinguish a smaller difference. A new difference is taken, until the subject gets about 70% of his answers right; this is then his difference threshold.

For the most accurate work the per cent of right answers required cannot be given as "about" 70; the threshold must be stated with the number of trials made and the exact per cent of right answers. For ordinary work, however, such a statement is probably sufficiently accurate to make possible the comparison of the capacities of different individuals. If the per cent of right answers is over 80, generally a new trial is made with a smaller difference; if it is under 60, a new trial with a larger difference is required.

Qualitative experiments and accurate descriptions. Up to this point the present chapter has dealt with quantitative studies in sensations. It will be apparent in many of the experiments that we are not interested in thresholds that can be measured, but are trying to discover the nature of the response. In other words, much of the experimental work is descriptive and qualitative. For such experiments the restrictions in scope that apply to quantitative studies do not hold, and the methods of investigation are those that belong to science in general—isolation of the phenomena to be studied, provision for repetition of the experiment, and the like.

Historical note. The experimentations described for quantitative studies on thresholds and for certain qualitative studies (for example, those that establish a relation between color sensation and the length of the light waves) have historically been discussed under the term *psychophysics.* Fechner (1801-1887) definitely worked on the problem of establishing a relation between conscious reactions and measurable physical changes. He first used the term psychophysics in 1860, and did pioneer work in the field. When Wundt opened the first psychological laboratory in 1879, for some years he directed his efforts to the same problem, although descriptive experiments occupied an important place in his work. The conception of establishing a relation between mental states and physical changes which could be measured became too narrow to cover the problems that pressed for solution—much experimentation appeared to be unrelated to the question. The term is still used to mean that part of psychology which shows the relation between the quality, the quantity, and the sequence of conscious states, and the kind, the intensity, and the order of time in physical stimulation. This special topic is generally most fully treated today in courses in physiological psychology, although many general courses in the subject make large use of the material.

Chapter 12, "Weber's and Fechner's Laws, and the rise of psychophysics," in Garrett's *Great experiments in psychology,* gives a more detailed account of some of the topics discussed in this section.

Section C.—Description and Localization of Sense Organs and Qualitative Reactions

EXPERIMENT 11.—MAP OF THE RETINA: COLOR ZONES

Problem. To discover the regions on the retina on which certain colors and lights can be seen.

Materials. A perimeter, and small triangles of white, blue, yellow, red, and green paper. A yardstick, painted black and fastened at the middle so that it can be turned through any angle from horizontal to vertical, may be used instead of the perimeter. Or large concentric circles drawn on the board before which the subject is seated may be substituted for the apparatus. A head rest should be provided for each subject in case the perimeter is not used. Small frames for holding the colors are an advantage, since these will expose the same area of color throughout.

Procedure. The entire experiment is performed on one eye, while the other is kept closed. The perimeter should be placed so that the dominant light lies behind the subject; a dark surface in the field of vision is advantageous. *S* adjusts his chin to rest on the apparatus and keeps the eye steadily focused on the center of the arc. Placing a white cross at the point to be focused will assist the subject; if the eye is moved the results are invalidated. *E* begins with a white triangle and places it at the extreme end of the semicircle, so that the point of it is clearly visible over the rim. The triangle is moved inward until the subject can see it; this position is noted in degrees, and the same point is determined for the other side of the retina and for its bottom and top. To check the position accurately, move the triangle from the center outward. Also note changes in the appearance of the colors as they are moved inward.

Repeat the process, with each of the 4 colors, 5 times. The average of the position found going inward and that going outward is taken as the limiting point on the retina.

Results. Report the original figures in the blank on page 58, and find the averages for white and the four colors. Locate the points on paper, and connect with lines to give a rough map of your retina. Observe that the light coming from the nasal side crosses the eyeball and falls on the side of the retina nearest the temple. The mean (*M*) of the five trials in each series is required. The average of the two means (*AM*) gives the point to plot on the map.

WHITE — RED

TR.	RIGHT		LEFT		UP		DOWN		RIGHT		LEFT		UP		DOWN	
	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN
1																
2																
3																
4																
5																
M																
AM																

GREEN — BLUE

TR.	RIGHT		LEFT		UP		DOWN		RIGHT		LEFT		UP		DOWN	
	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN
1																
2																
3																
4																
5																
M																
AM																

YELLOW — PURPLE

TR.	RIGHT		LEFT		UP		DOWN		RIGHT		LEFT		UP		DOWN	
	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN
1																
2																
3																
4																
5																
M																
AM																

Discussion and interpretation. The facts here found need to be interpreted in the light of a theory of color vision such as that of Hering. Before this can be done adequately, other facts must be established.

The points found for the different colors and for the white paper depend upon such factors as the strength of the stimulation, the size of the triangles, and the illumination of the room. For accurate results these must be under control.

The degree at which each of the different colors becomes visible is to be entered in the blank on page 58.

EXPERIMENT 12.—THE BLIND SPOT

Problem. The purpose of the experiment is to determine the following:

1. The fact that a blind area exists on the retina.
2. The approximate location of this area.
3. The nature of the response when light falls on the blind spot and on the area surrounding it.
4. The size and shape of the blind spot.

Materials. Ruler and pencil; an upright rod clamped to the table, or a head rest, to maintain position of the head; a 3 x 8 rectangle of white paper with a ½ inch circle near one end and a heavy dot near the other; a card with a design as described below in place of the circle. These cards with different designs may be secured from supply houses, but the simple construction here indicated will give accurate results.

Procedure. Close one eye, and look steadily at the dot on the card, with the circle in front of the open eye. The card should be 12 to 15 inches from the eyes. Move the card back and forth and sideways until the circle disappears from view. The reflected light from the circle now falls on the blind spot. *E* can determine by inspection the approximate position of the blind spot on the retina. Locate the blind area on the map of your retina.

To determine the nature of the response when light falls on the blind spot and on the area immediately surrounding it, some design needs to be drawn around the circle on the card. However, the design must not cover the area of the circle. A large letter *X*, the two intersecting lines of which stop at the circumference, will serve; or the area surrounding the circle may be colored. When the light from the circle falls on the blind spot and the light from the design falls on the retina surrounding the blind spot, the blind area is filled in to make a uniform pattern.

When the size and shape of the blind spot are being determined, the head must be kept in a stationary position while the subject is looking at

the card with the circle and the dot. The position of the head is partly fixed by placing it against one end of a vertical ruler supported on the table; the ruler supports the head midway between the eyes. An upright rod or a head rest will prevent lateral movements of the head. With the head in position, the card is adjusted on the table until the light from the circle falls on the blind spot. Now the experimenter (or the subject working alone may do this) moves the pencil across the card toward the circle. As the pencil nears the circle, a position will be found at which the point disappears from view; the light from the pencil point is now falling on the outer edge of the blind spot. The place is marked on the paper, and the process is repeated from other directions. Enough points should be located to show a rough outline of the invisible area. It should be noted that some subjects will get better results by substituting for the pencil a strip of paper $\frac{1}{4}$ inch wide which has been cut to a point and dipped in ink.

The approximate diameter of the invisible area is required for the next problem, that of finding the diameter of the blind spot. The blind spot diameter is found by noting the proportion between certain known distances. An additional fact, that of the distance from the lens of the eye to the retina, is required; in the average adult eye this distance is close to $\frac{5}{8}$ of an inch. If the diameter of the invisible area on the paper is $1\frac{1}{2}$ inches, the proportion becomes:

$$5/8 : 12 :: x : 1\ 1/2$$

Or $$12x = 5/8 \times 1\ 1/2 = 15/16$$

Then $$x = 1/12 \text{ of } 15/16 = 5/64, \text{ or approximately } 1/13$$

Accordingly, the diameter of the blind spot is about 1/13 of an inch.

Results. Reproduce the drawing of the invisible area, or paste the original drawing of the invisible area, in the blank below. Also give the calculation for the diameter of your blind spot.

Discussion and interpretation. 1. The filling in of the blind area when a pattern falls on the retina surrounding the blind spot has been explained by several theories. The phenomenon is probably related to the larger fact that stimulating one portion of the retina will arouse responses that ordinarily come from stimulating other parts, or that stimulating one eye will arouse a response that generally requires stimulation of the other eye. A later study on retinal rivalry and fusion presents related facts.

2. The diameter of the blind spot is generally found to be from 1/10 to 1/20 of an inch. It is irregular in outline.

Supplementary observations. 1. By means of an ophthalmoscope the interior of the eye can be examined. The blind spot, and also the fovea, are easily located.

Subjects may check themselves on their ability as observers by making repeated drawings of their blind spots. Careful observers have found the same size and shape over a period of years.

EXPERIMENT 13.—DEFECTS IN THE VISUAL SENSE ORGAN

Problem. To examine the eye for the following defects:

1. Near-sightedness and far-sightedness.
2. Astigmatism.
3. Color blindness.

Materials. The Snellen Chart for deficiencies in distance vision; a chart with radiating lines for astigmatism; the Ishihara Color Plates for color blindness. The experimental literature describes many other devices for measuring deficiencies in vision.

Procedure. Directions for making the various studies accompany the materials, and should be observed. The measurements for near-sightedness and far-sightedness are to be made without the use of spectacles, since these are worn to correct the defect.

Results. Report the results for each of the three studies in the blanks below.

Distance Vision

Distance for clear vision on chart......... ....

Ratio of distance......................... ....

Is vision normal, near-sighted, or far-sighted? ....

Astigmatism

Describe the position of the radiating lines at different angles.

Color Vision

Record the responses for each of the 16 plates in the Ishihara Test; for plates requiring tracing, report whether the tracing was correctly done.

1..........	5..........	9..........	13..........
2..........	6..........	10..........	14..........
3..........	7..........	11..........	15..........
4..........	8..........	12..........	16..........

Discussion and interpretation. Abnormalities in distance vision are usually due to defects in the lens of the eye; astigmatism results from a defect in the shape of the eyeball; color blindness indicates a deficiency in the cones of the retina. Defects in vision often lead to serious consequences in the development of the individual; the tests are simple, and should be in general use among those who work with children.

EXPERIMENT 14.—FUSION OF RETINAL PROCESSES: COLOR MIXING

Problem. To observe the result when a second stimulus starts a process on the retina before the activity started by the first stimulus has stopped.

Materials. Rotator or color wheel, with discs of red, green, blue, yellow, black, and white. It is often possible to fasten the color discs to the shaft of an ordinary motor; the electric fan motor has been adapted to the requirements of the experiment. Some demonstrations are possible with tops. A protractor is required for measuring the number of degrees of each color exposed.

Procedure. Determine the results from the following combinations: (1) yellow and blue; (2) red and green; (3) yellow and red; (4) blue and red; (5) green and black; (6) red and black; (7) red and white. Any

other colors may be tried with the black and white discs or with one another. Use 180 degrees of each color in one of the trials; also use other proportions to study the effects of different combinations.

Results. In the following blank, enter the results for the different combinations indicated above; in column *D* give the number of degrees of each color used in the combination.

Color	*D*	Result	*D*	Result	*D*	Result	*D*	Result
Blue								
Red								
Blue								
Green								
Red								
Yellow								
Blue								
Yellow								
Red								
Green								
White								
Black								

Discussion and interpretation. Interpret the results in terms of some color theory. For example, the result for the stimulation from yellow and blue is explained by saying that the yellow produces a katabolic and the blue an anabolic activity in the cones; the two neutralize, and gray comes from the activity of the rods. For yellow and red, katabolic activity in the cones in different zones on the retina is produced by both colors; the two fuse to give orange. The addition of white increases the rod activity to give different tints; the addition of black reduces the rod activity to give shades. This explanation uses the Hering Theory. No theory is generally accepted, and any other may be used to account for the phenomena

observed. To leave the problem by pointing out, for example, that certain colors in combination produce a certain effect because they are complementary, names a fact but does not explain it.

All possible hues, saturations, shades, and tints can be produced with the four colors and black and white. The experiment is to be continued until the result of any combination can be predicted with a good degree of accuracy; for each combination an explanation in terms of retinal processes should be given.

EXPERIMENT 15.—CUTANEOUS SENSE ORGANS

Problem. The purpose of the experiment is to locate the sense organs for: (1) touch; (2) pain; (3) cold; and (4) warmth.

Materials. Millimeter stamp or soft pencil to locate area on arm; stiff bristles from hair brush; iced water; heated water or sand; pointed brass rods or nails.

Procedure. On the palm side of the forearm an area is located either with the stamp or with a 6-inch straight line drawn with the pencil. For touch, the area is explored with a bristle fastened to the end of a match. The touch end organs at the roots of hairs should be noted. Pain end organs are very numerous and are readily located with the bristle if this is shortened and the pressure increased; the subject should be convinced that not all points on the skin give rise to pain. To discover the cold spots, a brass rod should be removed from the iced water, dried, and then lightly applied to different areas of the marked region. At times only touch will be felt; in some spots, however, a distinct cold sensation is aroused. If some of these cold spots are marked with ink, it will be possible to demonstrate that warmth is not received from the same spots; the rods taken from the heated sand or water are used to locate the warm spots.

Results. The experiment as described asks for qualitative data. The millimeter stamp or the straight line should be reproduced, in duplicate if necessary, and the various sense organs located.

Supplementary experiments. The experiments on qualitative responses here described cover only a very small portion of the total field. Even visual and cutaneous processes are presented only in their simplest manifestations. In vision, for example, the investigations could be continued

with experiments on positive and negative after-images, the hue, saturation, and intensity of colors, binocular vision, the processes of adaptation and inhibition, the effects of color contrasts, and the like. New fields lie in other sense realms, particularly hearing, taste, and smell. The next section, on quantitative studies, and a later chapter on perception, will introduce related investigations from a somewhat broader field.

Section D.—Lower Threshold and Difference Threshold: Quantitative Studies of Sensory Processes

EXPERIMENT 16.—LOWER THRESHOLD FOR LIGHT

Problem. To determine the least amount of light that will arouse a reaction on the retina.

Apparatus. Motor for mixing colors; large discs of black and white paper; smaller disc of black paper; circular protractor.

Procedure. The subject is seated at one end of a table, with the dominant light to the rear. The large discs are interlapped, with one degree of white showing, and placed on the color mixer. The small disc is placed in front of the larger ones on the same motor shaft. As the motor is turned the small black circle at the center will be surrounded by a circle with a small amount of white. The amount of white is now increased in different trials until *S* can see a difference in the light from the two circles. The number of degrees of white in the outer circle is the lower threshold of light for *S*.

The experimentation can be facilitated by the use of several color mixers, each with discs of different degrees of white. Several subjects can make the observations at the same time.

Repeat the determination by beginning with enough white to make the outer disc clearly grayer for *S*, and reduce the amount until the outer and inner circles appear to be equally black. Ten trials in the ascending and descending order are required for the approximate determination of the limen.

Results. Report your limen in the separate trials in the blank below. Find the average of the ascending and the descending series, and the average of these two.

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

Discussion and interpretation. 1. What method was used in the experiment?

2. The results in this experiment are affected by a large number of factors which are not under control: the length of time that the subject looks at the discs before he responds; the area of the discs; the portion of the retina that was stimulated; the physiological condition of the retina; the intensity of the light falling on the discs; the reflective power of the white and black surfaces; general conditions of fatigue; and the like. It is possible to control these variable factors, and thereby secure dependable measures of each subject.

3. The retina responds to an extremely wide range of light intensities. The complete series extends to an intensity that has been calculated to be more than a billion times the lower threshold.

4. If some light comes from the inner circle, will the result found be that of the lower threshold?

EXPERIMENT 17.—DIFFERENCE THRESHOLD FOR LIGHT

Problem. To determine how much difference must exist between two light stimuli in order that they may be discriminated.

Apparatus. The same as given for the experiment on the lower threshold, with the addition of a small white disc to be interlapped with the inner black disc.

Procedure. To the inner disc 180 degrees of white are added; this constitutes the standard and is kept unchanged throughout the experiment. The experiment could, of course, be performed with any other proportion of white. The outer circles begin with 181 degrees of white, and this is increased until *S* observes a difference between the outer and inner circles. The number of degrees of difference constitutes the subject's difference limen for the standard designated. The experiment is to be continued as described in the study of the lower threshold.

Results. Enter the measurements in the blank below, compute the average for the two series, and the final average.

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

Discussion and interpretation. 1. The experiment on the lower threshold is probably a study of the difference threshold, since black paper reflects light.

2. The factors which affect the reliability of the results on the lower threshold also enter into this study. The chapter by W. C. Beasley on

"Experiments in vision," in Valentine's *Readings in experimental psychology,* gives more refined methods for experiments on visual thresholds. This should be read, and the methods substituted for those described if the apparatus is available.

3. The Masson disc may be substituted for the method described. This is a white disc upon a radius of which a series of small black rectangles are drawn. The rectangle closest to the center constitutes a larger proportion of the circle on which it lies than any other rectangle. When the disc is rotated, a series of gray rings decreasing in intensity from center to circumference will be shown. The subject is required to indicate the faintest ring that is visible to him.

EXPERIMENT 18.—LOWER THRESHOLD FOR COLOR

Problem. To determine the least amount of color that will arouse a sensation.

Apparatus. Color mixer; discs of white, red, green, yellow, and blue paper; smaller disc of white paper. Protractor for measuring angles.

Procedure. The larger white disc and one of the colored discs are placed interlapped, with one degree of the color showing. The small white disc is placed on the motor to form an inner circle on the larger discs. *S* observes the turning discs and reports whether some color is visible in the outer circle. Small changes are now made in the number of degrees of color shown, until the subject names the color correctly. The number is recorded. The experiment is continued by alternately beginning with the color clearly visible and reducing it, and with no color visible and increasing it. Records are made for the ascending and descending series. There should be 10 trials in each series.

In the same manner the threshold can be found for the other colors.

Results. Enter the scores in the proper blanks, and complete the experiment according to the directions given for the study of the lower threshold for light.

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

EXPERIMENT 19.—DIFFERENCE THRESHOLD FOR COLOR

Problem. To determine the least difference that must exist between two colors in order that they may appear different.

Apparatus. The materials enumerated for the experiment on the lower threshold for color are required, with the addition of smaller discs of the four primary colors.

Procedure. The large discs of red and white are placed interlapped on the mixer; the small discs of the same colors are then added in such a way that they cover the center of the larger discs. In the smaller discs 180 degrees of red are exposed; this is kept unchanged throughout the experiment.

E now adjusts the larger discs so that 181 degrees of red are visible, and rotates the discs. If *S* sees no difference between the outer and inner circle, more red is added until *S* reports the two as different. The threshold is the number of degrees above 180 required for discrimination. *E* now begins with a red distinctly more than the difference threshold of the subject, and reduces the amount until the outer and inner circles look alike. This procedure is repeated until 10 ascending and 10 descending records have been taken. The same method is followed for other colors.

Results. Record the ascending and descending limens in the blanks below, and complete the experiment according to the directions given in the experiment on the difference threshold for light.

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

Discussion and interpretation. 1. For accurate limens the variable factors named in earlier experiments on vision need to be controlled.

2. *The selection of colour workers,* by W. O'D. Pierce, shows how studies of difference limens find practical applications in industrial fields.

3. Apparatus has been designed to vary the proportions of the two discs while they are being rotated. This should be used in place of the rotators if it is available.

EXPERIMENT 20.—LOWER THRESHOLD FOR SOUND

Note. People who work with children often need a method of measuring the sensitivity of hearing, with materials that are readily at hand. The method here described is in general use for this purpose. Each ear should be tested separately; if much difference exists in the sensitivity of the ears, the ear not being tested should be plugged with cotton.

Problem. To find the least stimulus that will arouse a sensation of sound.

Apparatus. Stop watch and ruler. To make the records comparable, all students should use the same watch.

Procedure. The subject sits about 5 feet from a wall, with one ear toward the experimenter. The experimenter determines roughly the range at which the watch can be heard. A table is placed in this position. *E* now begins definitely within the hearing distance of *S*, and moves the watch along the edge of the table (it should not touch the table) away from the subject. The subject reports "Now" when he can no longer hear the sound. The distance from *S*'s ear is measured, and the result recorded. The process is repeated by beginning beyond the range of hearing and gradually moving inward. This is repeated until 10 trials have been found for the ascending and for the descending series. Each ear should be tested separately; the ear not being tested is covered.

Results. Enter the results in the blank below, and find the average for each ear.

RIGHT EAR

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

LEFT EAR

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

Discussion and interpretation. Several subjects should be tested to find the norm. The intensity of the tick of different watches varies, and no standard can be given unless this is known.

Supplementary experiments. More refined methods of measuring the lower threshold for hearing are in common use. Seashore devised an instrument known as an audiometer, which produces 40 tones varying in intensity from those that are inaudible to those that are very distinct for the normal ear. Other audiometers vary the strength of tones at different pitch levels. These instruments should be used if they are available.

EXPERIMENT 21.—DIFFERENCE THRESHOLD FOR INTENSITY OF SOUND

Problem. To determine how large a difference must exist between the intensities of two sounds in order that the sounds can be distinguished. Since the standard intensity is not definitely stated in figures, the results will make comparisons possible only among individuals who take the same test under the same conditions.

Apparatus. Phonograph, and Seashore's record on the intensity of sound.

Procedure. The two tones which differ in loudness or intensity will come in close succession. The subjects will judge whether the second is weaker or stronger than the first. If the second is stronger, record *S;* if the second is weaker, record *W.* A short preliminary practice period should precede the experiment.

Results. Enter your judgments, as *S* or *W,* in the blank; proceed downward in each column. Space is provided on the blank for repeating the test.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

Number correct............................; percentile position............................

Discussion and interpretation. 1. The percentile distribution for the experiment has been worked out. After the answers have been checked against the key supplied with the record, the percentile rank should be entered in the personal data blank.

2. Which of the standard methods is used in the experiment?

3. Seashore's *Psychology of musical talent* should be read for the significance of this as well as several other tests that have been standardized to measure musical capacities.

EXPERIMENT 22.—DIFFERENCE THRESHOLD FOR PITCH

Problem. To determine the difference threshold for pitch.

Apparatus. Phonograph, and Seashore's record on pitch.

Procedure. The tones are produced by the record in pairs, one tone being higher than the other.

The student will judge whether the second sound is higher or lower than

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

Number correct............................; percentile position.............................

the first. If it is higher, record *H;* if lower, record *L.* There may be any amount of preliminary practice, but the answers are not to be memorized.

Results. Enter your judgments, as *H* or *L,* in the blank; proceed downward in each column. Space is provided for repeating the test.

Interpretation. The percentile distribution for adults has been worked out. Enter your score and percentile rank in the personal data blank.

EXPERIMENT 23.—DIFFERENCE THRESHOLD FOR LIFTED WEIGHTS

Introduction and problem. The experiment described below was performed by Weber, with different apparatus, shortly after 1830; he determined the difference threshold for a large number of standard weights (15 grams, 30 grams, and others), and extended the method to similar studies in other sensory fields, notably touch and vision. Weber's discovery that the threshold is not an absolute amount but a certain fraction of the standard was expressed as a law, which was later called Weber's Law. With further experimentation the law was confirmed for a limited range of stimuli.

The purpose of the experiment is to determine how much heavier a second weight must be than a given standard, in order that the two weights can be distinguished. In technical language, the purpose is to find the difference threshold for lifted weights.

Apparatus. Two specially constructed holders, the weight of each to be 90 grams; metal rings ranging in weight from 10 to 24 grams, with differences of 1 gram; a wire loop weighing ½ gram. An upright rod or other means to indicate a distance of 6 inches from the table; blindfold or screen. The materials may be secured through the Marietta Apparatus Co., of Marietta, Ohio.

Procedure. The weights are placed on a table, beside which *S* is seated. Either a blindfold is arranged, or a screen is interposed, between *S* and the weights. A height of 6 inches from the table is shown on an upright rod near *S*'s hand.

E now places the 10-gram ring on one of the holders, and a heavier ring, say that weighing 20 grams, on the other. One weight, designated hereafter as the standard, will weigh 90 plus 10 grams, or 100 grams, and the other 90 plus 20 grams, or 110 grams. *E* places one of the weights between the thumb and forefinger of *S*'s preferred hand. *S* hefts the weight by lifting it steadily to the indicated height of 6 inches, and replaces it on the table; *E* immediately substitutes the second weight, which *S* lifts as he did

the first. *S* now reports whether the second weight was lighter or heavier than the first. This process is repeated about 5 times for the same pair of weights. If all the answers are correct, *E* substitutes a lighter comparison weight, and continues testing. As soon as *S* makes an error in his responses, the exact limen is to be found by the method of right and wrong cases described below.

Both the subject and the experimenter should follow the instructions carefully in every detail. (1) The height to which the weights are lifted must be kept constant throughout the experiment. (2) The subject should lift each weight slowly and steadily to the indicated height, and immediately replace it. The normal movement that is made when a small object is hefted should be used. The subject should not jerk the weight upward, nor swing it sideways, nor hold it after it has been hefted. (3) The subject should not be given a second trial if the two weights appeared to be identical; the report should be either "lighter" or "heavier," even if the judgment is a guess.

After the approximate difference limen has been found in accordance with the method here described, the exact limen is determined by presenting the two weights in chance order for 20 trials; each weight must be presented first the same number of times. The blank for the final series of 20 trials, given on page 74, is the form to use for all series. The difference threshold for *S* is found when 75% of the trials are correct. If a larger percentage of the subject's estimates is correct, a lighter comparison weight is to be used. It may be necessary to use the wire loop weighing ½ gram to arrive at a limen that will result in the correct number of responses. *S* is to continue with the experiment until one series of trials gives a percentage of correct answers lower than 75; due to the fact that certain factors are not well controlled and that the number of trials is small, a subject may receive a score of 75% with two different limens.

Results. In the proper blanks enter: (1) the responses in the final successful series, in full; and (2) the results in each of the other series that were tried, in the order in which they were taken. The proper facts should be recorded in the class summary blank and the personal data blank in appendix C.

S is to continue with the test until he fails with a smaller limen than the one accepted. In reporting the final series, check the correct responses by means of a plus sign, and errors by means of a minus sign; place the sign under the weight lifted last.

Discussion and interpretation. 1. Why not use 50% as a standard for passing the test, rather than 75%? Would there be any objection to using 100%?

Standard Weight	*Comparison Weight*	*Per Cent Correct*	*Final Series Standard 100*	*Final Series Comparison* ....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
100	....	....	....	....
			Correct	....
			Per cent correct	....

Difference limen: .... — 100 = ...

2. Note whether subjects showed a tendency to call the second weight heavier. Errors in experimentation that tend to repeat themselves are known as constant errors.

3. A subject scored 75% correct with a difference of 6 grams in the two weights, and 80% with a difference of 5 grams. Account for results of this type.

4. Plan an experiment for determining whether a small difference limen is of advantage in certain life activities. Some evidence indicates that a small difference limen is required for success in certain fields of music. It possibly plays a part in work such as that of a surgeon or of a mechanic—work involving the use of precision instruments.

5. Plan an extension of the experiment to try out Weber's Law.

Supplementary experiments. The experimentation on weight limens can readily be extended, with the same apparatus, to include the limen for the non-preferred hand, and also for both hands. To determine the limen when both hands are used, one of the weights is held by the right

hand and the other by the left, and the two are hefted simultaneously; each hand lifts the heavier weight the same number of times.

Results of Measurements on Weight Limens

College Women (60 Cases)

	Preferred Hand	*Non-Preferred Hand*	*Both Hands*
75th percentile	5.3	7.0	6.0
50th percentile	6.4	7.9	7.8
25th percentile	8.3	9.0	8.3

CHAPTER 6

The Selection Among Stimuli: Attention

The nature of the attentive process. The organism is constantly assailed by many stimuli. For example, a person waiting for a train could at any instant respond to any one of hundreds of stimuli: the pressure on his feet; the warm atmosphere; the kinesthetic stimuli from a package he is carrying; the pain from a tight shoe; the touch of his spectacles and of his clothes; the sounds of voices and footsteps, of trucks and taxis, and literally scores of other auditory stimuli; the sight of any one of many faces, of styles in clothing, of the activities of people, of buildings and materials; and so on to include every aspect of the environment in which the individual finds himself. He could respond to any stimulus situation within the limits of his capacities.

The important fact to observe, however, is that the person does not respond indiscriminately but selectively; he responds to some stimuli and ignores others. In referring to this selective aspect of behavior, we use the term *attention.* From the objective point of view attention is the name given to the fact that an individual responds selectively. Introspectively the individual will observe the stimulus situations to which he responds as clear and distinct, and others as faint and fleeting. Accordingly, we define attention introspectively as the name given to the fact that some responses at a given moment are clear and distinct and others are faint and fleeting.

Although a person ignores most of the stimuli that play upon him, the neglected material is not without some effect. It constitutes a background, a marginal zone for the central elements to which we respond. The reality of this margin is demonstrated when we notice while we are engrossed in reading, that a clock stops ticking; the ticking must have had some effect during the time that reading was focal, or the ceasing of the ticks could not have produced a response. What is marginal may become focal at any instant. The marginal responses are also important in explaining behavior such as suggestion. For the present, however, we are to examine experimentally certain facts of the focal response.

Many problems grow out of the fact that we respond selectively. To

how many stimuli does the organism react at one time? Since there is a limited number to which it can react focally, what determines which will be reacted to? What happens, specifically, when two stimuli are presented at the same time and continue in operation together? After the organism reacts to a given stimulus, does this reaction tend to continue or do other stimuli tend to intrude? During the time that a particular reaction to some particular stimulus is in progress, how resistant is the process to change or interruption? How do individuals differ in their attentive reactions?

A complete analysis of this topic requires a chapter in a text. The following experiments will introduce the student to some of the experimental methods and to significant results in the field.

EXPERIMENT 24.—SPAN OF ATTENTION FOR ISOLATED UNITS

Warning. *S* must not see the material before he responds to it in the experiment.

Problem. To determine the number of simple units to which *S* can react at the same moment.

Apparatus. A tachistoscope, or a focal-plane photographic shutter. The experiment can be performed with a group by using a projection lantern provided with a camera shutter that will permit the timing of the exposure. Specially prepared cards of figures, letters, or dots, with 3 to 15 units on each. These are procurable through supply houses.

Procedure. The apparatus is designed to permit only a single, momentary view of the material presented; *S* must not be given time to shift his eyes for a second view. The time should be 1/10 of a second or less. Before the material is shown, *S* focuses his eyes on the surface where it will appear. The cards are now shown in the order of the number of units, beginning with the card having the fewest. After each card is shown, *S* makes a record of the units comprehended.

The method of right and wrong cases gives an accurate result after the approximate span has been found. Suppose the approximate attention span to be 7 units; by showing cards with 7 and 8 units according to the method of constant stimuli, the exact span can be found.

Results. Enter the results in the blanks below, and also in the class summary and personal data blanks. Describe the group performance in level and variability.

Subject: digits..................; letters..................; dots..................

Group mean: digits..................; letters..................; dots..................

Group SD: digits..................; letters..................; dots..................

Discussion and interpretation. 1. It is possible that *S* does not react to the different units at the same moment. Some evidence indicates that the after-image supplies part of the data. This difficulty can be minimized by exposing the elements in faint light, or the after-image may be obliterated by having *S* look at a card with an unrelated picture.

2. The stimulus which arouses a response is not necessarily a single physical unit, but may be a group of such units.

3. Find the intercorrelations between the different measures of the span of attention. Do subjects retain their relative positions when different material is used?

4. Determine by the correlation method whether the attention span is related to the capacities measured in other experiments.

5. Some individuals have defective pupils that admit the light from a very limited range; only one or two letters may be visible. Such "pin point" pupils lead to difficulty in reading and spelling.

RESULTS OF MEASUREMENTS OF THE ATTENTION SPAN

College Women (72 Cases)

	Digits	*Letters*	*Dots*
75th percentile	6.9	6.0	9.0
50th percentile	6.3	5.6	8.1
25th percentile	5.9	5.0	7.3

Cattell found a span of four digits for adults: fewer letters are seen in one span. The results from college sophomores lie between 4 and 8 letters and 5 and 11 dots. Due to the fact that all factors are not under control, the norms vary widely; the results from the experimental group to which *S* belongs are probably most reliable for determining his position.

EXPERIMENT 25.—EYE SPAN IN READING

Problem. In reading, the eyes move from left to right along the line of print, in a series of short, jerky movements. The eyes function only while stationary. Accordingly, it is possible to determine how many words are comprehended during each fixation of the eyes. This is the problem of the experiment.

Apparatus. Small mirror attached to frame, with strap for fastening to subject's head above the eyes; page of material to be read. Or printed page pasted to card, with pin hole through middle of card and page.

Procedure. Complicated apparatus which photographs the eye on a moving film during the process of reading is in use for this study. The mirror device gives fairly accurate results, in the hands of experienced ob-

servers. The mirror device is fastened to the head of the subject, so that the eyes can be observed from the side while the reading is in progress. The printed page on a card is in common use; *E* counts the eye movements by looking through the small hole while *S* reads. The movements may be observed in an ordinary mirror placed beside the book from which the subject is reading.

Results. *E* makes a record for each line of a complete page, by either or preferably both methods suggested. By determining the number of fixations for a line, it is possible to compute the average number of words that were comprehended at each fixation.

In the following blanks, enter for the different lines the average number of words comprehended in each fixation.

1..............	7..............	13..............	19..............	25..............	31..............
2..............	8..............	14..............	20..............	26..............	32..............
3..............	9..............	15..............	21..............	27..............	33..............
4..............	10..............	16..............	22..............	28..............	34..............
5..............	11..............	17..............	23..............	29..............	35..............
6..............	12..............	18..............	24..............	30..............	36..............

Discussion and interpretation. 1. The result is often called the *apprehension span* rather than the *attention span.* What is the difference between the two?

2. Enter your results in the proper blanks, and compare your record with that of the experimental group.

Results of measurements of reading span. The span of college sophomores has been found to be a little less than two words for reading new material from a text in psychology. Difficult lines show so many back and forth movements that it is impossible to count them. The abler student has a larger span than those who have difficulty in comprehending the content read. Individual differences are large; as many as fifty fixations have been found in some people for lines of print that others read in four. The span is often given in letters instead of words.

EXPERIMENT 26.—SPAN OF ATTENTION FOR ACTIVITIES

Problem. To determine to what extent two activities can be carried on simultaneously.

Materials. Watch; two pencils and paper.

Part A.—Routine Activities

Procedure. (*a*) The subject will draw triangles with his left hand for a period of 30 seconds; the side of each triangle is to be about 1 inch in length. Five trials are required. (*b*) He will next draw squares with his right hand; the length of each side is to be 1 inch. Five trials of 30 seconds each are required. (*c*) The final task is to perform the two operations at the same time; 5 trials of 30 seconds each should be taken. The quality of the drawings under the different conditions should be kept uniform.

Results. The score in each case is the number of figures drawn. Enter the numbers in the following blanks.

Separate Activities			*Combined Activities*		
Trial Number	*Left Hand*	*Right Hand*	*Trial Number*	*Left Hand*	*Right Hand*
1	....	....	1	....	....
2	....	....	2	....	....
3	....	....	3	....	....
4	....	....	4	....	....
5	....	....	5	....	....
Average	(*a*)..............	(*b*)..............	Average	(*c*)..............	(*d*)..............

Gain or loss........................%

The gain or loss is computed in terms of the amount done with the two hands working separately. The following calculation will illustrate the method. Assume the score for the left hand working separately to be 10, and the score for the right hand 20; when the two hands are working together the score for the left hand is 6, and for the right hand 12. The left hand does 6/10 as much, and the right hand 12/20 as much, in combined as in separate activities. Together they do the sum of these fractions, or 12/10 as much; this represents a gain of 2/10. The formula $(c/a+d/b)-1$ represents the fractional increase obtained by combining the activities of the two hands.

Interpretation. By combining the scores from the experimental group, determine the per cent gained in performing the two activities at the same time. Note whether all subjects gain, and whether there is a large variation in the gains made by different subjects.

Part B.—New Activities

Procedure. (*a*) Add alternately 3 and 8, continuously, to a number to be given to you by *E*; thus, if *E* gives 9 for the beginning number, your results will be 12, 20, 23, 31, 34, 42, and so on. This should be done for 30 seconds. Repeat 5 times for your score in this activity. Begin each time with a different number. (*b*) Write the alphabet backwards for 30 seconds; take 5 trials and use the average as your score. (*c*) Perform the two activities at the same time; take 5 trials.

Trial	*Adding*	*Writing*	*Adding*	*Writing*
1	....	....	....	....
2	....	....	....	....
3	....	....	....	....
4	....	....	....	....
5	....	....	....	....
Av.	(*a*)..............	(*b*)..............	(*c*)..............	(*d*)..............

Gain or loss......................%

Interpretation. 1. By combining the scores from the class, determine the percentage of gain or loss when two new activities are performed.

2. Report on fluctuations of attention from one task to the other in both types of combination activities. To observe this, repeat each activity if you cannot recall how the two activities were carried on.

3. What conclusions do you draw with reference to attending to two activities at the same time?

EXPERIMENT 27.—SIMULTANEOUS STIMULATION: INHIBITION AND FUSION

Problem. To determine the effect on reactions if two stimuli, approximately equal in their stimulating capacity, act on sense organs at the same time.

Part A.—Simultaneous Stimulation of Hot and Cold Spots

Materials. Hot and cold water; metal rods.

Procedure. Apply the heated and the cooled rods to the back of the hand, about an inch apart, and hold them for a second. Do this repeatedly until the response can be clearly described.

Results. Make a definite statement covering your observations.

Part B.—Simultaneous Stimulation of Right and Left Retinas

Materials. Squares of glass of different hues. A stereoscope with cards which have a different color for each eye will give good results. Specially drawn figures for the stereoscope will extend the investigation.

Procedure. *S* holds a glass of different hue before each of his eyes, and reports to *E* the following facts: (1) when the color before the right eye is inhibited; (2) when the color before the left eye is inhibited; (3) when both are seen; (4) when the two are fused. The report will state briefly what is seen throughout the trial. Each pair of glasses should be held before the eyes for 3 minutes; several combinations, such as red and blue and yellow and blue, should be used.

Results. Report the data in the blank below.

S reports what he sees with the colors named before each eye; use the initial letter for each of the colors, a plus sign for both colors seen at the same time, and *f* for fused colors.

Left Eye	*Right Eye*	*Visual Responses in Order*
R	*B*	....
B	*R*	....
Y	*R*	....
R	*Y*	....
Y	*B*	....

Interpretation. 1. Do the sensations from temperature and from colors tend to fuse?

2. After fusion, did you observe any difference in the strength of the persisting response?

3. How do complementary colors affect the rate of alternation?

4. Discuss the bearing of the experiment on the problem of attention.

EXPERIMENT 28.—FLUCTUATION OF ATTENTION

Problem. To determine the rate of fluctuation of attention to stimuli that can be interpreted in more than one way.

Materials. Two reversible figures given in appendix B: (1) Scripture's Blocks; and (2) a reversible cross. Pencils and paper for subjects, and a watch for experimenter.

Procedure. *S* should observe that both the figures may be seen in two

ways: the cross is either a white cross on a black background, or a black cross on a white background; the blocks may be seen as either 6 or 7. The figures should be closely observed until the double appearance of both has been clearly seen.

During the experiment one of the figures should be covered. At a signal from *E*, the subject looks steadily at the figure, and notes carefully the reversals; he reports each reversal, which is tallied by *E*. At the end of one minute a rest period of 30 seconds is introduced. Fifteen trials should be taken with each figure, on two different days; the score for each figure is the average of the two trials.

Results. Enter the original scores in a blank in appendix C. The mean for the 30 trials with each figure is to be entered in the blanks below. The group description requires the score from each student.

Subject mean: blocks........................; cross........................

Group mean: blocks........................; cross........................

Group SD: blocks........................; cross........................

Interpretation. 1. Find the coefficient of correlation between the scores from the class on the two figures. Do people who fluctuate in their attentive process in one situation also fluctuate in another?

2. Relate the results of this and other experiments to the expression "the concentration of attention." Subjects may repeat the experiment to determine whether the attempt to hold one perspective affects their scores.

EXPERIMENT 29.—RESISTANCE OF SENSORY PROCESSES TO INTERRUPTION

Problem. To determine how strongly the organism resists a change or an interruption when it is reacting to a particular stimulus.

Materials. Masson disc with motor; watch; metronome; phonograph.

Procedure. *S* finds the gray ring, made by the turning disc, which is at his threshold. The outer zone of the disc will appear white and the inner portion will show gray rings which become more distinct as the center of the disc is approached. The faintest ring that *S* can detect is the threshold for *S*, and to this he should respond.

When *S* has found his threshold, a second stimulation is started. A metronome or a phonograph record is satisfactory. The change in threshold is noted, and also the length of time that the change persists. At least 5 trials should be made; *S* points out the new ring that has become visible, and *E* times the subject until the original ring again constitutes the threshold. The score includes both the extent of change in terms of

the number of rings, and the time before the original threshold again becomes focal.

Small fluctuations come without the interrupting sound, and these should be observed by each subject.

Results. Enter the scores in the proper blanks, and report each for the class summary.

Trial	*Extent of Change*	*Duration of Change*	*Trial*	*Extent of Change*	*Duration of Change*
1	....	....	6	....	....
2	....	....	7	....	....
3	....	....	8	....	....
4	....	....	9	....	....
5	....	....	10	....	....
			Average	....	....

Interpretation. 1. Describe the effect of the second stimulation.

2. Are the differences large enough to make possible a classification of individuals on the basis of their ability to resist interruption?

3. Would you expect the disturbances in a noisy city to raise thresholds?

4. Plan an experiment to show the effect of disturbances on activities such as multiplying.

CHAPTER 7

The Acquisition of Adaptive Reactions: Learning

In some of the experiments described in previous chapters, casual reference was made to the fact that the organism whose responses we are studying undergoes changes that are relatively permanent. Modifications, both qualitative and quantitative in nature, result as the human being adapts itself to environmental conditions. The adapting reactions may consist in driving a car, serving a tennis ball, understanding or speaking a language, changing from an indifferent attitude to one of sympathetic understanding, acquiring insight into mathematical processes, losing the fear of high places, and so on to cover every aspect of life that involves changes in the response. Any change in a person that lasts longer than the temporary neuro-muscular set has come about through the process called learning.

The problem of learning is too large for adequate experimental treatment in an introductory course. The methods by means of which it is investigated are shown only in their most general application.

EXPERIMENT 30.—CONDITIONED RESPONSE

Problem. One of the most significant forms of learning is that by which a new stimulus comes to produce the same effect that an old stimulus produced before. The same fact is stated by saying that a response is connected with a stimulus that did not arouse it before. The new act is a *conditioned response,* and the new stimulus a *conditioned stimulus.* The problem of the experiment is to trace the development of a conditioned response.

Apparatus. An electric circuit for lighting a small lamp or ringing a bell. A second circuit, with battery, key, and an inductorium; in the secondary circuit of the inductorium are two small brass plates so placed that the hand of the subject will complete the circuit.

Procedure. *S* is seated at the side of the table, with the apparatus. The two brass plates are adjusted so that the finger tips and the palm of the hand, one on each plate, will complete the circuit. When the primary

circuit is closed, *S* will receive a slight shock; this should be adjusted in strength to cause *S* to withdraw the hand.

Before the beginning of the experiment the bell is rung and the lamp lighted to demonstrate that *S* will not respond with a hand movement to either stimulus.

In the experiment proper the bell is rung, and immediately after this stimulus the electric shock is given. The two are given in this order until *S* removes the hand at the sound of the bell without the shock. The combination stimuli should be continued until *S* removes the hand 3 times in succession in response to the bell stimulus; the response on the part of *S* must, of course, be involuntary.

Results. Number the trials, and keep a record of the responses both to the current and to the bell. A blank is provided for this purpose. Note particularly the first hand response to the bell stimulus, and also when the conditioned response has been established for 3 successive trials.

In the blank, enter the result for each trial: write *b* if the response was made to the bell, and *c* if it was made to the electric current.

1..........	13..........	25..........	37..........	49..........	61..........	73..........	85..........	97..........
2..........	14..........	26..........	38..........	50..........	62..........	74..........	86..........	98..........
3..........	15..........	27..........	39..........	51..........	63..........	75..........	87..........	99..........
4..........	16..........	28..........	40..........	52..........	64..........	76..........	88..........	100..........
5..........	17..........	29..........	41..........	53..........	65..........	77..........	89..........	101..........
6..........	18..........	30..........	42..........	54..........	66..........	78..........	90..........	102..........
7..........	19..........	31..........	43..........	55..........	67..........	79..........	91..........	103..........
8..........	20..........	32..........	44..........	56..........	68..........	80..........	92..........	104..........
9..........	21..........	33..........	45..........	57..........	69..........	81..........	93..........	105..........
10..........	22..........	34..........	46..........	58..........	70..........	82..........	94..........	106..........
11..........	23..........	35..........	47..........	59..........	71..........	83..........	95..........	107..........
12..........	24..........	36..........	48..........	60..........	72..........	84..........	96..........	108..........

Interpretation. 1. Read for class discussion the following chapters in Garrett's *Great experiments in psychology:* chapter 4, "Pavlov and the conditioned reflex"; chapter 7, "Watson's experimental studies of the behavior of the human infant."

2. The time required for establishing a conditioned response under the conditions of the experiment is generally long. The experiment may serve as a demonstration only. If a number of subjects perform the experiment,

the score of each in terms of the number of trials required to establish the reflex should be entered in the proper blanks for comparative purposes.

EXPERIMENT 31.—ELIMINATION OF WRONG MOVEMENTS: MAZE LEARNING

Warning. *S* must not see the maze before the experiment.

Introduction. A fact as important as the acquisition of new responses to old stimuli, studied in the experiment on the conditioned response, is the elimination of movements that do not serve the organism. This process can be observed on a large scale in a person who is trying to find his way about in a city or who has difficulty in locating a book in a library. The first efforts include many needless movements, but these are finally eliminated. We would probably ascribe the learning to certain conscious adjustments that the person had made, but such a description would leave the problem in terms that themselves would require explanation.

The fundamental processes that occur to eliminate wrong acts are not revealed by general observation of people. Under controlled conditions the elimination of movements can be accurately observed and the process definitely described. A controlled experiment in the field is that of requiring a subject to find his way through a maze which has one correct pathway to a goal and many opportunities for errors. It is found that the conditions are simplified and a more complete record of what occurs can be made if the subject finds his way without the help of vision.

Problem. To observe the learning of a maze.

Apparatus. A maze, with a screen or a blindfold; watch. Many forms of mazes are in use at the present time. The one for which the procedure here given is intended is known as a *T* maze, because of the shape of the raised wire which *S* is to trace with his finger. The wire units have the form of a *T*, each with one blind alley and one correct path that leads to the next *T*. The blind alleys are numbered so that *E* can keep a record of the errors made in tracing. Different forms of mazes furnished by supply houses may be substituted in the experiments.

Procedure. *S* should understand the procedure to be followed, but should not see the maze until the experiment has been completed. The maze is placed on a table before the blindfolded subject. *S* will have his finger placed at the beginning of a raised pathway which ultimately leads to a goal; some turns will lead toward the goal, and others away from it. At the word "Begin," *S* is to find the way as quickly and with as few errors as possible to the end of the pathway. *S* will be told when the end has been reached; another trial will be started and this is continued until *S* goes through the entire pathway twice in succession without errors.

E starts the timer when *S* begins a trial, and records the time required

Trial	*Time*	*Errors*	*Trial*	*Time*	*Errors*
1	....	....	31	....	....
2	....	....	32	....	....
3	....	....	33	....	....
4	....	....	34	....	....
5	....	....	35	....	....
6	....	....	36	....	....
7	....	....	37	....	....
8	....	....	38	....	....
9	....	....	39	....	....
10	....	....	40	....	....
11	....	....	41	....	....
12	....	....	42	....	....
13	....	....	43	....	....
14	....	....	44	....	....
15	....	....	45	....	....
16	....	....	46	....	....
17	....	....	47	....	....
18	....	....	48	....	....
19	....	....	49	....	....
20	....	....	50	....	....
21	....	....	51	....	....
22	....	....	52	....	....
23	....	....	53	....	....
24	....	....	54	....	....
25	....	....	55	....	....
26	....	....	56	....	....
27	....	....	57	....	....
28	....	....	58	....	....
29	....	....	59	....	....
30	....	....	60	....	....

to reach the goal. *E* also makes a record of the number of the blind alleys that *S* enters going forward, and also those that he enters in case he retraces any part of the pathway from the goal. The record for the different trials will appear as follows:

Trial	*Time*	*Errors*
1	7′ 45″	3, 5, 9, 11-9, 11, 13, 17, 19-15-11, 13, 15, etc.

The dash between the numbers of certain alleys indicates that the error was made going backward.

Results. 1. Summarize the results on time and errors for the different trials in the blank on page 88.

2. In the following blank tabulate the number of times an error was made for each alley.

Alley	*Errors*	*Alley*	*Errors*	*Alley*	*Errors*	*Alley*	*Errors*
1	....	21	....	41	....	61	....
3	....	23	....	43	....	63	....
5	....	25	....	45	....	65	....
7	....	27	....	47	....	67	....
9	....	29	....	49	....	69	....
11	....	31	....	51	....	71	....
13	....	33	....	53	....	73	....
15	....	35	....	55	....	75	....
17	....	37	....	57	....	77	....
19	....	39	....	59	....	79	....

Interpretation. 1. Make a record of the results on a bar diagram, showing on the same page the time and the errors.

2. The course of learning for the class as a whole is found by taking the average of all subjects for each of the trials. Two or three students should work this as a project and report the results to the class. This course should be shown graphically, the time and the errors being shown on separate pages.

3. Superimpose your time and errors graphs over the composite graphs of the experimental group. Compare your own graphs with those of the group in such respects as rate of improvement, periods of greatest progress, rate of learning at the beginning, and so on.

4. The total time and the total number of errors constitute individual scores that are entered in the proper blanks and interpreted as described in former experiments.

5. Did you stress accuracy or speed in the course of learning the maze? Show how this is determined.

6. Summarize the results from the class as a whole, to determine the order in which the different alleys were eliminated. This should be completed by two or three students and reported to the class.

7. Was the elimination of the wrong movement a planned, conscious process, or did the finger seem to take the right course of itself? Give any other significant introspective data on the learning of the maze.

8. What explanation of learning finds support in the results from the group?

9. In Garrett's *Great experiments in psychology,* read chapter 5, "Thorndike's animal experiments and laws of learning."

EXPERIMENT 32.—MUSCULAR LEARNING AND BILATERAL TRANSFER

Introduction. It is difficult to place an adult in a situation corresponding to that of a child engaged in learning muscular activities. We possess an equipment of learned movements which can be adapted to any situation that presents no new requirements. The learning of such activities as playing an instrument—which can be successfully observed in the adult—does not parallel that of the child when it learns to pick up objects and throw them, or when it attempts more complicated activities such as that of writing. In mirror drawing, which is the activity to be studied in this experiment, the former experiences of the individual play a relatively small part.

The data from the experiment will serve to throw light on a second problem, that of the transfer of learning from one hand to the other.

Problems. 1. To study the course of learning in tracing lines visible only in a mirror.

2. To determine whether learning in one hand affects the ability of the other.

Apparatus. Mirrors and screens so arranged that the subject sees his hand only as it is reflected in the mirror. Pencil and timer. Thirty-one patterns of a six-pointed star. The patterns of the star should be drawn by the subject. They can be readily drawn by tracing around the stiff cardboard model. The star measures 4⅝ inches between opposite outside

points, and 2⅝ inches between opposite inner points. A cross-line to show the starting point is placed at one of the inner angles of each star. The stars are numbered in the order in which they are used.

In place of the design on paper, a star-shaped path one-fourth inch in width, cut in metal, may be used. This method was developed by Dr. George S. Snoddy of the University of Indiana, and has been extensively used under his direction. The metal plate is placed in an electric circuit, with an electric counter, a stylus, and a key to make and break the circuit. When the stylus touches the side of the star in the closed circuit, the counter is activated. Niches are cut into the sides of the star to prevent continuous contact between the stylus and the metal plate.

Procedure. The mirror is stood upright on a table, preferably held by a clamp. A screen is interposed about 10 inches above the table, in a horizontal position, so that *S* can see the movements of his hand only by looking into the mirror. Under the screen, fastened with thumb tacks to a piece of cardboard, is the star pattern, turned so that the cross-line is nearest to the mirror.

S examines the apparatus, and adjusts the mirror so that his hand is clearly visible when it is in position for writing on the star pattern. *S* is to trace the outline of the star by watching his movements in the mirror only. The pencil must follow the outline exactly; if the pencil leaves the line it must be brought back before continuing. *S* is to proceed as rapidly as possible, with a minimum of errors. *E* will give the signal for starting, and record the time for each tracing.

S will first make 3 tracings with the unskilled hand, then 25 with the preferred hand, and finally 3 with the unskilled hand. Count the errors for each tracing. Whenever the pencil leaves the line, or goes in a wrong direction when attempting to return to the line, an error is made.

The same procedure described for the designs on paper is followed when the metal star is used. The stylus is first placed in position, at the point on the side of the star farthest to the left; the tracing proceeds in a direction contrary to the movements of the hands of a clock. When the stylus is in position, *E* gives the signal to begin tracing; at the same moment the key is pressed to close the circuit and the timer is started.

The subject is to regulate his speed of tracing so that the time in seconds is approximately equal to the number of errors; *E* should give directions with reference to increasing or decreasing the rate as the tracing on the part of *S* proceeds.

Results. Enter the time and errors for each trial in the blank on page 92. Observe that 3 trials with the unskilled hand are to be taken at the beginning, and 3 at the end.

PREFERRED HAND

TRIAL	1	2	3	4	5	6	7	8	9	10	11
TIME											
ERRORS											

TRIAL	12	13	14	15	16	17	18	19	20	21	22
TIME											
ERRORS											

TRIAL	23	24	25		1	2	3	4	5	6
TIME										
ERRORS										

Interpretation. 1. On separate sheets of graph paper, plot the progress in learning for the time taken, and the number of errors made.

2. Compare your curve with the composite result from the class. To get the composite result, take the average of all *S*'s for each of the trials, in both time and error. Draw the two graphs for the class on the same page with your own. Colored ink can be used to advantage in making a clear representation of the facts.

3. Compare your own performance with that of the class in as many respects as possible.

4. How much transfer is found for the unskilled hand when the skilled hand is trained? From general observation, would you expect this training to affect other muscles also; for example, those controlling the elbow or the foot? Is there evidence that the organism tends to react as a unit?

5. Did those subjects who served first as experimenters secure a better record than those who were subjects first? Find the average of each group separately. Does watching another perform a task help the observer?

Results of Measurements on Mirror Drawing

The following composite results for the time required are based on the records of 82 students; the time is expressed in seconds.

Preferred Hand

Trial	*Time*	*Trial*	*Time*	*Trial*	*Time*
1	147	9	22	18	12
2	97	10	20	19	13
3	53	11	19	20	10
4	40	12	19	21	10
5	33	13	17	22	10
6	29	14	16	23	9
7	25	15	15	24	9
8	24	16	15	25	9
		17	14		

Unskilled Hand

Trial	*Time*
1	225
2	183
3	150
4	83
5	76
6	70

EXPERIMENT 33.—ASSOCIATIVE LEARNING

Warning. *S* must not examine the blanks before the experiment is begun.

Problem. The learning studied in preceding experiments has dealt largely with motor adjustments. The investigation proceeds naturally from this type of learning to that which consists of the formation of associations between symbols. The motor processes serve only to record the progress in learning, without themselves being subjected to modification. This form of learning can be objectively studied in the substitution test, one type of which will constitute the basis of this experiment.

Materials. For subject, blank with letters and digits (appendix B), and pencil; watch for experimenter.

Procedure. At the head of the blank are thirteen letters of the alphabet, with a number after each. In the body of the blank are the same letters, followed by a space for recording the number which appears opposite the letter at the top of the blank. *S* is to place the proper number in the blanks following each of the letters; the work is to proceed from left to right; every blank is to be filled in as it occurs. At intervals of one minute *E* will give a signal; *S* is to draw a distinct vertical line after the last substitution to indicate the amount completed, and is then to continue

with the test. The experiment is continued until all the substitutions have been made.

The substitutions in the second blank should be completed in the same manner, on a succeeding day.

Results. Enter the number of substitutions for the different trials in the blank below; the total time will be approximately equal to the number of trials.

Trial	*First Blank*	*Second Blank*	*Trial*	*First Blank*	*Second Blank*
1	....	....	15	....	....
2	....	....	16	....	....
3	....	....	17	....	....
4	....	....	18	....	....
5	....	....	19	....	....
6	....	....	20	....	....
7	....	....	21	....	....
8	....	....	22	....	....
9	....	....	23	....	....
10	....	....	24	....	....
11	....	....	25	....	....
12	....	....	26	....	....
13	....	....	27	....	....
14	....	....	28	....	....

Interpretation and questions. 1. Graph your scores in each form by representing the trials on the base line and the number of substitutions on the vertical.

2. Find the average of the group for each trial in both forms, and graph the composite group result on the same paper with the graph of your own scores.

3. Compare your own curves with those representing the group.

4. Is there any difference between the progress in associative learning and that in muscular adjustments?

5. In the class summary blank, enter as your score the total time required in each form. Determine your position in the experimental group.

CHAPTER 8

Complex Conscious Reactions: Perception and Reasoning

Perception is the central meaningful reaction from which the sensation studied in earlier experiments was abstracted for separate investigation. The indefinite expression *knowing an object* must, for scientific purposes, be displaced by the definite word *perception.* It means, from the conscious side of life, *awareness of objects,* including under "objects" not only the material world of chairs and trees, but time, space, movement, and organic conditions. The term awareness of objects does not include such abstractions as sweetness, kindness, blueness, and the like. In the experiments which follow, the central problem will be that of determining how we understand or become aware of objects.

This problem has been approached by trying to determine how much of an object needs to be shown in order that it will be recognized. A bicycle, for example, is represented in the first drawing by a part of the frame, in the second a part of a wheel is added, then a portion of the saddle, and so on until the object is represented fully. This type of investigation is interesting, but it reveals very little of the process.

Better results have been obtained with the perception of words and sentences. Words are shown with some of the letters omitted—as, *t-l--h--e* for telephone—and the time required to find the meaning is taken as a quantitative index of the process. In a similar way words are omitted from sentences, and the time required to supply them is measured. The process studied here involves more than is ordinarily meant by perceiving, but the experiment is important.

Due to the difficulty of experimenting on the awareness of objects, much of the laboratory work deals with the perception of the other facts mentioned—time, direction, location of points touched on the skin, location of distances in the visual field, the direction of sound, determining how definitely we know the movements we make, how accurately we know whether one or two points are being touched, and the like. The student must undertake the investigation of these questions for the purpose of determining how the awareness of objects is developed as one of our reactions. Taken in themselves, the investigations are relatively unimportant. The whole question of illusions must be approached from the standpoint of the light it throws on the normal perception of objects.

Experiments on learning are displacing some of the older experiments on perception. The careful study of how a foreign language is acquired, how a vocabulary is increased, and how children learn to read may be interpreted as a process of perception.

EXPERIMENT 34.—SPACE PERCEPTION BY MEANS OF TOUCH

Problem. In an earlier experiment the end organs of touch were located. The contact with the bristle gives not only the sensation of touch, but we also localize it. This localization constitutes a perception of position on the skin, and can be experimentally studied.

Apparatus. Jastrow's aesthesiometer. An inexpensive substitute can be made from a rubber eraser about 2 inches long and three short pins with small heads. A millimeter scale about 2 centimeters long is drawn in ink on one side of the eraser; two of the pins are pushed into the eraser on the scale, and the third into one end of the eraser.

Procedure. Note the construction of the apparatus. The distance between the two points can be regulated by a thumb screw and read directly from the scale on the aesthesiometer. The sliding attachment on the handle serves as a means for holding the instrument. When the instrument is lowered on *S*'s hand, the pressure is always constant, being equal to the weight of the instrument. The volar side of the forearm, about midway between elbow and palm, is to be explored for spatial perception. The points are to be applied crosswise.

The two points are touched so that the weight of the instrument rests on the arm; the distance between the points should be large enough so that *S* clearly perceives the points as two. *E* now decreases this distance until *S* perceives the two points as one. This distance is recorded, and the instrument is set to a distance distinctly less than that which *S* can discriminate. The two points are now applied, and the distance increased until *S* perceives them as two. This distance is entered in the blank. At least 5 ascending and 5 descending trials should be taken. At times the arm should be touched with only one point when the distance is larger than *S*'s limit.

The experiment can be performed with the eraser and pins by the method of right and wrong cases. The approximate distance is first found, and then 20 trials are made by touching the subject with one and then with the two points in irregular order; the judgments of the subject are entered in a blank, and when 75% are correct the distance for the two points has been found. If a larger percentage is correct, the pins are placed closer together; if the per cent correct is less than 75, the experiment is continued with a larger distance. The experiment is continued until the subject falls below 75% on one of the series of 20 trials.

Results. Enter the two-point limen for *S* and for the group in the blanks below. The group description is based on the distance found for each individual in the group.

Subject mean: ....; group mean..................; group SD..................

Discussion. 1. If the same areas are not touched throughout the experiment, a larger difference tends to be found. Why?

2. A child has a smaller two-point limen than an adult. Account for this.

EXPERIMENT 35.—PERCEPTION OF TWO POINTS ON THE RETINA

Problem. To determine the capacity of the retina to perceive two stimuli lying very close to each other.

Materials. On a square of white cardboard, two strips of black paper are pasted. Each strip should be $\frac{1}{8}$ inch wide and $\frac{3}{8}$ inch long. The two are placed $\frac{1}{8}$ inch apart. The length of the two strips should be exactly equal to the distance between the two outer sides of the strips.

Procedure. *S* is seated at a table, with his chin on a rest to make sure that the same position will be kept during all the trials. One eye is covered. *E* takes the card to the opposite end of the room, and holds it so that it can be clearly seen by *S*. He then approaches *S* slowly, until the two strips of paper are seen as two. A table is placed in this position, and the distance is more definitely determined by the method of minimal changes. *E* begins at a point distinctly beyond the range of *S*'s vision, and approaches slowly toward *S*. The place at which the two strips become visible is marked, and its distance from *S* is measured. Now *E* begins from a distance clearly within the range of *S*'s vision, and removes the cardboard farther until *S* reports that the two strips have fused. The distance is again recorded. The card should be moved slowly but continuously until *S* gives his report. Twenty trials, 10 ascending and 10 descending, should be taken.

Results. Enter the scores in the blank below. Find the average of each series and also the average of the last two averages. This is the distance at which *S* can perceive two stimuli on the retina as two.

TRIAL	1	2	3	4	5	6	7	8	9	10	AV.	AV.
INC.												
DEC.												

Interpretation. 1. Find the distance between the two points stimulated on the retina, by the method described for finding the diameter of the blind spot. This distance should be entered in the class summary blank for comparative purposes.

2. A rod on the retina is about 1/14,000 of an inch in diameter. Relate this fact to the distance between the two-point perceptual distance found in the experiment.

3. The distance changes with certain factors, such as lighting and fatigue of the eye. With other factors held constant, the distance has been used as a measure of fatigue.

EXPERIMENT 36.—PERCEPTION OF SYMBOLS: READING

Problem. An earlier experiment studied the movement of the eyes during reading. This and the following experiment will investigate other aspects of reading. In the present experiment the subject's rate in silent reading will be determined.

Materials. A story and an essay written on the adult level; watch.

Procedure. The experiment is performed outside of class hours. The same story and essay are to be used by all subjects. *S* determines the time required for reading both types of material. The reading is to be done at the best ordinary rate with comprehension.

Results. Count the number of words read. This can be done rapidly by determining the average number of words in a line, and then counting the number of lines on a page. Short lines of conversation need to be counted separately.

Report in the blanks below the average number of words read in a minute for both types of material. The record of each subject is to be reported for the class summary blank in order that the group may be described.

Subject mean: story......................; essay......................

Group mean: story......................; essay......................

Group SD: story......................; essay......................

Discussion and interpretation. 1. Determine your relative position in the group, in terms of decile or quartile.

2. Do subjects read different types of material at the same relative rate?

Results on the rate of reading. The difficulty of the material read, the degree of comprehension with which it was read, and the length of time that the reading was continued are some of the factors that influence the

rate of the subject. The range in scores is very wide. The average rate per minute for essays (93 subjects) is 218 words; individuals range from 154 to 335 words. The average rate for stories (96 subjects) is 330 words; the range is from 175 to 440 words. Short selections are read at a higher rate.

Subjects have been found who apparently read up to 1000 words in a minute. Generally, only topic sentences are read, and a glance at key words suggests content with which the subject is familiar from former reading.

EXPERIMENT 37.—KNOWLEDGE OF WORDS

Warning. The test must not be examined until the experiment is begun.

Problem. The subject's knowledge of the non-technical words used in college work will be investigated.

Materials. The words on which the subject is to be examined are part of a long list contributed by students as words which are used in discussions but which are not clearly comprehended. All words that belong to particular courses and to specialized fields have been excluded. The words aim to present a cross-section of the subject's vocabulary in the area in which it is both expanding and increasing in definiteness. The list is found in appendix B.

Procedure. The words are presented in the following form:

1. a *piquant* manner: (*a*) irritable; (*b*) amiable; (*c*) lively; (*d*) dejected (........)

The italicized word *piquant* is to be defined by one of the four words which follow it; one of the four words gives the best definition or synonym for the word as used in the expression. In this case the best synonym is *lively;* the letter for this word (*c*) is placed in the parentheses at the right of the statement. The best definition is to be chosen in every case, and the letter to the left of this definition is to be placed within the parentheses. The time for the test is not limited; it is generally completed in 35 minutes.

Results. Check the number of errors by means of the key accompanying the blank, and find the gross score by counting the number of words marked correctly.

The gross score combines the words that are known with those that were guessed. In a test of 100 words, the subject who knows only 80 would receive a score of 80 plus ¼ (since there are 4 items for each word from which *S* makes a choice) of the 20 words to which the answers were

guessed. His answer would be 80 + 5, or 85, instead of the true score of 80. A correction is necessary.

This correction is made by substituting in the formula

$$x = 85 - \frac{100 - x}{4}.$$

The symbol x represents the true score, 85 the gross score, and 100 the number of words which were defined. The formula will give the correct score irrespective of the number of words that the subject attempts to answer. For example, if in a test of 125 words the subject checks 120, of which 100 are right, the calculation is

$$x = 100 - \frac{120 - x}{4}$$

$$\begin{aligned} 4x &= 400 - 120 + x \\ 3x &= 280 \\ x &= 93\tfrac{1}{3}. \end{aligned}$$

Enter in the following blanks the gross score and its corrected value, for both the subject and the group.

Subject: gross score........................; corr. score........................

Group mean (corr. score)........................; SD........................

Discussion. With few exceptions, the difficult words for college students lie above the 10,000 words most frequently used, as given in the list of Thorndike. Different forms of the test here used contain approximately 1 out of every 25 words from this list. Students with a score of 30 on the present test define practically all the 10,000 words. The average of 57 words probably indicates a vocabulary of at least 14,000 basic words, since this average has been found for college students. For each basic word it was found that, on the average, the student knows 2.8 other words derived from it. The technical words depend on the special field in which the student works; when the lists of non-technical words were compiled, the number of special words growing out of certain courses was estimated at 2,300. One may probably conclude that the average sophomore has a vocabulary in excess of 50,000 words.

The conclusion has to be left in general terms, since the statement "knowing a word" is in itself quite indefinite; we know certain words precisely in several meanings, and others only in a particular limited use. The present test serves its purpose if it reveals to students their stage of growth in knowledge of words.

EXPERIMENT 38.—PERCEPTION OF PATTERNS

Problem. The nature of pattern perception is a problem that has been emphasized by the Gestalt psychologists. The present experiment will attempt to reveal some of the processes in pattern perception.

Materials. The test devised by R. F. Street, *A Gestalt completion test,* issued by the Bureau of Publications, Teachers College, Columbia University.

Procedure and results. The directions for giving and scoring the different patterns are provided with the test.

Interpretation. Read the discussion accompanying the test, and also chapter 11, "Köhler's experiments in perception and learning and their importance in Gestalt psychology," in Garrett's *Great experiments in psychology.*

EXPERIMENT 39.—DISCOVERING RELATIONS: REASONING

Warning. Neither *E* nor *S* should examine the blanks until both have performed the experiment.

Introduction. In perception, the individual reacts to definite stimulation which results in the awareness of objects. If the individual is confronted with a problem, this reaction to the objects before him is not merely a reaction to them as objects; he will notice aspects and clues about the objects, and especially certain elements in relation to others. The process which is directed to the solution of a problem is known as *reasoning.*

Reasoning should not be regarded as an activity that is entirely different from some of those that have already been investigated. Seeing various elements as a unit, as revealed in the study of pattern perception, is often an essential element in the reasoning process Learning that involves responses to *aspects* of the total situation and that includes *verbal* responses tends to become identical with reasoning, provided a problem is recognized in the activity.

Problem. The ability to discover relations in prescribed material will be investigated.

Materials. A test blank is provided in appendix B. The experimenter will require a watch.

Procedure. The test blank consists of exercises of the following type:

$$6 \qquad 4 \qquad 7 \qquad 3 = 3.$$

The requirement of the test is to discover the processes that were performed with the first four digits to give the answer, 3. The subject is to

place the proper symbols (+, —, ÷, ×) between the numbers, so that the result will be correct. The exercise, when completed as required, will read:

$$6 - 4 + 7 \div 3 = 3.$$

The same symbol may occur twice or three times in the same exercise. Thus, in the following:

$$2 \qquad 3 \qquad 5 \qquad 9 = 21,$$

the required processes are:

$$2 \times 3 \times 5 - 9 = 21.$$

If certain exercises give undue trouble, they should be omitted. Two 10-minute periods are allowed for the test; mark the exercises that were completed during the first period, so that they can be identified. The test is corrected by checking the process between the first two numbers; if this is correct the other two are assumed to be correct also.

Results. The score is the total number of exercises correctly completed in the two periods; report this for each period separately.

First period........................; second period........................; total........................

Group mean:........................; group SD........................

Interpretation. 1. Your performance is to be compared with that of the group.

2. The experiment is more important for the light that it throws on the processes involved, than for the individual differences that it reveals. Point out what impressed you as the essential character of the reasoning process.

CHAPTER 9

Sequences in Reactions: Association

Preceding experiments have assumed the fact that at the completion of one reaction another occurs. There is a sequence of reactions to the single overt stimulation, instead of the inactivity of the organism until another stimulus arouses it. To illustrate the facts of life here stated: A person is aroused by a step on the porch. Without additional stimulation, he may pass through a series of reactions which could include the consciousness of friend, a certain book to borrow of him, other reading to be done, and the like. It is possible that the muscular response of the original stimulation constituted the stimulation of the second response, and so with those that follow. The problem of this chapter is to discover the actual connections that exist for a given individual, without regard to the possible explanation of the problem.

EXPERIMENT 40.—KENT-ROSANOFF ASSOCIATION TEST

The associations of any individual become significant when they are compared with those commonly made by others. To determine the common association, 100 words were given to 1000 adults, and the responses were tabulated. For some words, the responses are centered on a few associations, while for others they are spread over many. With this standardized test it becomes possible to compare individuals in the usualness or the uniqueness of their associations.

Problem. To determine, for a given list of stimulus words, certain aspects of the associative connections.

Materials. A blank containing the Kent-Rosanoff words is reproduced in appendix B. The most complete frequency tables are given in Johnson O'Connor's *Born that way;* Rosanoff's *Manual of psychiatry* gives the tabulation for 1000 subjects.

Procedure. Probably the best results are obtained by giving the test individually, but the method for the group is commonly followed and will be indicated here. At a signal from *E, S* is to record on the blank, opposite the words found, the first word that occurs to him. The experiment must

proceed for the entire 100 words. While the experiment is in progress, *S* is to check every word for which the association was considerably delayed; at least 10 should be checked in this manner. When the experiment is completed, *S* will use the frequency table to determine how many out of 1000 have the same associations as those given by him. The frequencies for each of the 100 words should be recorded in the space following each of the words.

Results. Find the average frequency for the 100 words; enter this in the blank below, and also report it in the class summary for the description of the group.

Subject mean........................; group mean........................; group SD........................

Interpretation. 1. Find the average frequency of your associations, on the basis of the table. Compare this with the averages found by other members of the class.

2. Which average, a high one or a low one, indicates that the subject's associations for the stimulus words are the same as those which are commonly made?

3. Compare the number of entirely new words given by the different members of the class. Interpret this in terms of the completeness with which different subjects share ordinary experiences.

4. Illustrate how a mental set would affect associations.

5. What is the significance of the delayed associations? Does this appear true in your case? How could the validity of this hypothesis be experimentally tested?

6. How far can the results be interpreted to mean differences in originality or other traits in the subjects with different scores?

7. Correlations between traits of the subjects and the scores here found are low. Several correlations follow.

Score and general originality	.09
Score and common information	.44
Score and grades	.17
Score and tendency to be misunderstood	.48

The rankings for originality, for the possession of common information, and for the tendency to be misunderstood, were made by students who knew the subjects very well; in most cases the students were members of the same fraternity. The relation of being misunderstood is significant. It appears that people who are different from other people in their reactions to words show a form of behavior that affects their relations with others.

EXPERIMENT 41.—FREE ASSOCIATIVE TEST

Problem. It is often valuable for a student to study the train of associations that come in series without any intervening stimuli and without a determining tendency operating in the individual. The object of this experiment is to study these series of associations under entirely free conditions and also under limited control.

Materials. Paper, pencil, watch with seconds hand. For the free association study, three stimulus words, such as *chalk, winter, river;* these are to be selected by the instructor and supplied to the subjects written on cards. For the study of the partially controlled association, the stimulus words are selected from the field of student activities, such as sports, music, recreation, and the like. The words are given on cards, with the field designated from which new words are to be selected.

Procedure for free association. Begin with each of the three stimulus words, and write the associative words as they come to you. Each should be a separate word, not a phrase or sentence. Continue until associations do not come readily; the total time should not be over three minutes. Do this for each of the three words. As far as possible, record the first associations that come to you in the sequence of words.

Results. Include with your report the complete list of words.

Procedure for partially controlled associations. The stimulus words will in this case be in the field of some activity; for example, athletics. Give as many associations as you can from the particular field. The directions will limit the field, but subjects should go beyond the field if necessary—give any associations that occur to you, but work under the mental set established by the instruction. Continue as long as words come to you, but the total time should not be more than three minutes.

Results. Enter in the following blanks the number of words in the test.

Stimulus Word	*Free Association*	*Stimulus Word*	*Controlled Association*	*Dominant Types of Words*
....	....	....	....	....................(..........%)
....	....	....	....	....................(..........%)
....	....	....	....	....................(..........%)
....	....	....	....	....................(..........%)

Interpretation. 1. Compare the average number of words in your free association list with the average of the class. What possible significance might be attached to the difference in the number of associations by different individuals?

2. For the free associations, determine the number of distinct themes that were followed, and the length of each. Omit doubtful words. Compare your results with that of the class, and indicate the possible significance of the differences among individuals.

3. Is there a tendency for certain words or classes of words to dominate your association train? Look for abstract words, or adjectives, or action words. Compare the group in this respect, and indicate the possible significance of your findings.

4. For the associations under limited control, find the number of associations bearing on the topic, and compare the individuals of the class. What is the possible significance of the difference found?

CHAPTER 10

The Retention of Experiences: Memory and Imagination

The earlier experiments on learning reveal one of the components of memory: any fact, to be retained, must first be learned. In addition to learning, the term memory covers *retention, recognition,* and *recall.* The experiments which follow will investigate problems in the fields here named.

EXPERIMENT 42.—MEMORY SPAN

Problem. The number of units that can be reproduced perfectly after one presentation is the span of the individual's memory. This will be investigated for two types of material and two methods of presentation.

Part A.—The Auditory Span for Digits

Materials. The combinations of digits required for the experiment are given in appendix B.

The experimental material consists of digit spans varying in length from 5 to 13 inclusive; 10 of each length are required—10 of 5, 10 of 6, and so on. One of each of the nine different lengths from 5 through 13 constitutes a series.

The experiment is sometimes performed by presenting all the 5-digit spans in sequence, then all the 6-digit spans, and so on through 13 digits; it appears, however, that a better measure of the individual is obtained by presenting the different lengths in irregular order. In the material provided, one of each of the nine lengths is presented, then a second series of nine different lengths is given, and this procedure is continued until the ten units of each span have been presented.

In devising the different spans, the 7 and the 0 have been omitted, because the word for each of these consists of two syllables. The digits are not given in consecutive order, nor in combinations that represent familiar dates.

A metronome that is moderately quiet, or an adjustable pendulum, is needed for timing; subjects require pencil and paper, and a card to cover what has been written.

Procedure. The timing device is adjusted to give 90 signals per minute. The experimenter reads the digits at the rate of one for each unit of time. The reading should not accent certain digits or combine any into groups. Immediately after the last digit in a unit has been read, the subject writes the digits in the order in which they were presented; one second is allowed for the writing of each digit. The subject covers his written work before the next unit is read. The ten series are read without interruption. The subject later checks his responses with the spans as given in the original blank.

Results. The memory span score in any series is the largest number of correct spans before a failure, plus one for each span written correctly after a failure. Thus, a subject who passes on 7 digits, fails on 8, passes on 9 and 10, and fails on 11, 12, and 13 has a score of 7 plus 2, or 9. The final score is the average of the 10 series.

Enter the score for each of the 10 series in the blank on page 109; compute the average, and enter this in the blank for the class summary.

Part B.—The Visual Span for Digits

Materials. The experimental material is the same as that used for part A.

The experimenter will require a 4 × 6 inch card, in which a slit about 1 1/2 × 3/16 inches has been cut; a timing device indicating seconds is also needed. Subjects should have pencils and paper, and a card for covering the part of the experiment that has been completed.

Procedure. The subject is seated at a table, in good light, with the page of digits provided in appendix B before him. The experimenter adjusts the card over the first digit span, so that the digits will be visible through the narrow slit; the subject is now asked to look at the digits that are exposed; the time allowed for each digit is 2/3 of a second. (A span of 6 digits is exposed 2/3 of 6, or 4 seconds; one of 8 digits is exposed 2/3 of 8, or 5 1/3 seconds.) After the exposure time has elapsed, the subject immediately attempts to write the digits that he saw; the subject is allowed one second for writing each digit—6 seconds for a 6-digit span, 8 seconds for 8 digits, and so on. Immediately after the time allowed for writing, the next unit is presented. This procedure is continued, without interruption, for the 10 series.

The time should be announced by an assistant.

Results. The method described in part A is used in determining the subject's score. The score in each series should be entered in the blank on page 109; the average for the 10 series is reported for the class summary blank.

Part C.—The Auditory Span for Letters

Note. Students who were experimenters for parts A and B of the experiment should use the materials of parts C and D when they become subjects.

Materials. The letters required for the experiment are given in appendix B.

The combinations of letters are similar to the combinations of digits used in parts A and B; the letters used are *b, j, d, f, t, r, l,* and *n.* No vowels are included, and combinations that could be readily interpreted as a word are avoided.

Procedure. Follow the method described for part A.

Results. The method of scoring is described in part A. Enter the scores in the blanks below, and report the average for the class summary blank.

Part D.—The Visual Span for Letters

Materials. The experimental material is the same as that used for part C.

Procedure. Follow the method described for part B.

Results. Score the results and treat the data as described for part A.

Scores in Memory Span Experiment

Series	*Part A*	*Part B*	*Part C*	*Part D*
1	------------------	------------------	------------------	------------------
2	------------------	------------------	------------------	------------------
3	------------------	------------------	------------------	------------------
4	------------------	------------------	------------------	------------------
5	------------------	------------------	------------------	------------------
6	------------------	------------------	------------------	------------------
7	------------------	------------------	------------------	------------------
8	------------------	------------------	------------------	------------------
9	------------------	------------------	------------------	------------------
10	------------------	------------------	------------------	------------------
Total	------------------	------------------	------------------	------------------
Mean	------------------	------------------	------------------	------------------

Discussion and interpretation. 1. Find your relative position in the experimental group in terms of quartile or decile, and enter this in the

personal data blank. The results given from other studies in the field will enable the subject to locate his own record within groups.

2. Find the coefficient of correlation between the scores in the different parts of the experiment. Do people who have a large auditory memory span tend to have a large visual span? Are the memory spans for different types of material related? Discuss.

3. Examine the scores in the 10 series for evidence of learning.

4. Distinguish between the attention span, described in an earlier experiment, and the memory span.

5. Read for class discussion chapter 3, "Ebbinghaus's studies in memory and forgetting," in Garrett's *Great experiments in psychology.*

6. The experiment on memory span has been extensively used in the study of children; the span increases with age, and is significantly related to the intelligence of the individual. Norms have been established for different ages. In adults the span is not closely related to general mental ability. Some evidence indicates that the more efficient stenographers and telephone operators have a large memory span. In general, the correlation between the memory span and other mental measures is positive but low. The correlation between different memory spans, such as those for different materials, is above .50.

7. Read for class discussion the investigation by John Gray Peatman and Norman M. Locke on "The methodology of the digit-span test," in *Archives for psychology,* May, 1934.

Results of Measurements on Visual and Auditory Spans

	Part A	*Part B*	*Part C*	*Part D*
75th percentile	8.2	9.7	8.6	9.9
50th percentile	7.4	8.6	7.7	8.9
25th percentile	6.2	8.2	6.7	8.4

EXPERIMENT 43.—WORD MEMORY

Problem. The preceding experiment investigated the amount that could be recalled as a single unit. Words, either isolated or in sentences, could have been employed in place of the digits and letters. A related problem consists of determining the amount that can be recalled from a body of material distinctly larger than the memory span. The experiment will determine the number of words that can be recalled out of lists of 20.

Materials. For *E,* 10 prepared lists of words, in appendix B. Pencil and paper for *S.*

Procedure. The 20 words are to be pronounced distinctly by *E*. Immediately after they have been presented, *S* writes all that he can recall. After 3 seconds the second list is read, and so on for the entire series. The lists should then be checked; the score is the number right.

Results. Enter the score for each trial in the blanks below, and find your average in the 10 trials.

Trial	*Remembered*	*Trial*	*Remembered*
1	....	6	....
2	....	7	....
3	....	8	....
4	....	9	....
5	....	10	....

Average number remembered: subject....................; group....................

Interpretation. 1. Find your position in the group in terms of quartile or decile.

2. The scores from this and other memory tests should be compared to determine whether the various aspects of memory are related.

Results from other measurements on word memory. For 74 subjects an average of 8.6 words was found. The range was from 6 to 15.

Supplementary experiments. The effect of repeating a word two or more times can be studied by substituting a word used in an earlier list for one or more of the words given in later lists. The words starred on the blank may be interchanged for such a study; additional substitutions may be made for a more detailed analysis of the question.

EXPERIMENT 44.—A STUDY OF RECOGNITION

Warning. Do not examine the blanks before performing the experiment.

Problem. The ability to recognize words previously presented will be quantitatively studied.

Materials. One hundred words from those presented in the last experiment, and 100 new words, are presented in irregular order. The list of 200 words is given in appendix B.

Procedure. *S* endeavors to check on the list all the words that appeared in the former experiment.

In order to make comparisons among individuals and groups possible, the recognition test should be given immediately after the words in the word memory test have been read to the subjects, and before the results

have been checked. The two experiments are given in immediate succession, and the scoring of both is done later. The aim is to have the contact with the old words the same for all subjects.

Results. After checking your performance, report the following facts.

a. Number of words correctly recognized ....

b. Number of words omitted ....

c. Number of new words mistaken for old words . ...

Final score: $a - (b + c) =$ ....

A perfect score would be 100 for *a* and 0 for *b* and *c*. A single score for the test is found by subtracting the sum of *b* and *c* from *a*. This is to be regarded only as an approximate score, since the manner of combining the three part scores into a single score has not been scientifically determined.

Interpretation. 1. Enter the scores in the proper blank, and determine your relative position in the group.

2. Compute the relationship between the scores in this test and those in the other tests of memory.

3. Describe the process of recognition as you experienced it in the study.

EXPERIMENT 45.—MEASURING THE AMOUNT FORGOTTEN

Problem. Several of the earlier experiments on learning can be readily adapted to the problem of measuring the amount forgotten at different times after the learning was completed. The measure of the amount forgotten is made in terms of the time required to relearn the material. Several other methods for measuring the rate of forgetting have been devised. For example, if the original learning consists of mastering a hundred words in a foreign vocabulary, we determine the amount forgotten by the number of words that can no longer be defined. This gives reliable results when different subjects are tested on the same material; however, the fact that the words which cannot be defined have not been entirely forgotten makes this measure inaccurate for certain purposes.

The method of measuring on the basis of the time required to relearn the material was employed by Ebbinghaus in a long series of experiments which he conducted about 1885. The result of his investigations is often quoted, and the following experiment is in a sense classic. The experiment will use the method employed by Ebbinghaus to measure the amount retained, or its converse, the amount forgotten.

Materials. Watch with seconds hand; list of nonsense syllables in appendix B.

Procedure. The 20 nonsense syllables are to be memorized until they can be repeated twice in succession without error. The subject should learn them by repetition, from beginning to end, without writing them. Any places of special difficulty may be given separate drill. Note the time at the beginning of the learning period and at its end.

Relearn the same syllables after one week, and note the time required for the relearning. The same standard of learning—two perfect reproductions in succession—should be used. No attention should be given to the syllables during the intervening week.

Results. Give the time for the original learning, and the time for the relearning; the difference represents the amount forgotten. Compute the per cent that was forgotten, and enter this in the proper blanks.

	Subject	*Group*
Time for original learning . . .	....	....
Time for relearning	....	....
Per cent forgotten	....	....

Report the individual record for the description of the group.

Interpretation. 1. Find your relative position in the group with respect to the capacity investigated.

2. Do people who learn slowly in this experiment retain better what they have learned than those who learn rapidly? Determine this mathematically.

3. Should the conditions under which the syllables are learned at the different periods be kept uniform? Discuss.

EXPERIMENT 46.—DOMINANT TYPE OF IMAGERY

Problem. To determine the degree to which an individual depends on different types of images.

Materials. Pencils and paper for subjects. For experimenter, the list of words and phrases given in appendix B.

Procedure. The subject should be reminded that images may be of as many kinds as we have sense organs. *S* may cover the words and phrases, and move the paper to show one at a time, or the words and phrases may be read by *E*. *S* should assume a passive attitude, and simply observe what occurs. As *S* experiences the reaction, he is to determine the kind of image he employs. If the imagery is all of one type, a score of 6 should be given to that type; if the imagery is divided between two or more kinds, the 6 points should be divided to show the relative strength of each kind. Thus, visual may be given 4, and auditory 2; in all cases the points should

total 6. The division may be made among three or more kinds of imagery. If it is not possible to classify the imagery, *S* should not force a decision, but as many as possible should be recorded. If a verbal image occurs, it is to be expressed in its basic form of imagery as visual, auditory, or kinesthetic. Care should be taken not to confuse the images of moving objects (including the subject in motion) with true kinesthetic images.

Results. Summarize your record for each type of image in the blank below.

	Score
Visual	76
Auditory	4
	4-6

Interpretation. 1. What type of imagery occurs most dominantly for you?

2. How do you compare with the class in this kind of imagery?

3. What method is used in this experiment? Are the results as convincing as those found by objective measurement?

4. Do the subjects fall into well defined types on the basis of their imagery?

EXPERIMENT 47.—USING RECALLED FACTS

Problem. Earlier experiments investigated the ability to recall facts in the exact form in which they were learned. In the present experiment the facts are to be recalled and used in new combinations. The activity appears to be closely related to what is considered an essential element in imagination, since the manipulation of old material is involved.

Materials. Lists of numbers of five and six digits, given in appendix B.

Procedure. The numbers are read to the subject, and he is to reproduce the series, first in the exact order presented, and then with the digits rearranged in a new order. For example, the experimenter reads the numbers 4-7-5-9-2. The subject reproduces this in the form presented, and then recombines the same digits in other forms, such as 4-7-5-2-9, 4-7-9-5-2, 4-7-2-9-5, 4-2-7-5-9, 7-9-5-2-4. Subjects should see the possible combinations of the original five digits; note that any new order of the same digits is acceptable.

The experimenter writes the numbers as the subject gives them; if the original series is incorrectly reproduced, it should be reread. The subject does not see what is written, nor is he told whether his new combinations use the required digits. As soon as *S* stops giving recombinations, a new number is read; this procedure is continued for 25 trials in each of the 5-digit and 6-digit series.

Results. The original reproduction of the series is not to be counted in the score. The score is the number of correct recombinations given by *S;* if two or more combinations are identical, only one is to be counted. It is generally possible for *S* to check the errors as the test is given. The final score in each series is the mean of the 25 trials.

Enter the original scores in the blanks in appendix C. Compute the mean for the group, and give both the individual and the group description below.

Subject mean: 5 digits......................; 6 digits......................

Group mean: 5 digits......................; 6 digits......................

Group SD: 5 digits......................; 6 digits......................

Interpretation. 1. In the experimental group, is the score with 5 digits related to the score with 6 digits?

2. Determine the intercorrelations between the present test and others in apparently similar fields. Is light thrown on the nature of the capacity involved?

Results of Former Measurements

	Five Digits	*Six Digits*
75th percentile	18	12
50th percentile	16	10
25th percentile	12	6

EXPERIMENT 48.—RECALL OF PATTERNS

Warning. *S* should not examine the designs until the experiment is begun.

Problem. The recall of visually perceived patterns involves processes that are possibly absent in verbal recall. Experiments of this type have been used to study the clearness and completeness with which images visually perceived are held. The experiment attempts to study objectively the degree of accuracy with which the subject can reproduce patterns that have been perceived.

Materials. Two patterns given in appendix B; pencil, and twelve sheets of paper about 4×5 inches; watch for *E*.

Procedure. One of the designs is to be covered during the time that the tests on the other are in progress. Before the experiment begins, *S* is told that a pattern will be exposed for brief periods and that he is to draw this as accurately as possible after it is covered. Attention is to be given to: (1) the number of lines in different parts of the design; and (2) the relative length of the lines. This may be shown with a design that is not to be used. The design is now exposed for 15 seconds, and then covered; *S* reproduces the design as accurately as possible. After *S* has completed the drawing, the design is exposed again for 15 seconds, and the drawing is made as before. This procedure is continued for 6 trials with each design. The reproductions are numbered.

Results. No very satisfactory methods of scoring the designs have been developed. The omissions and errors are of all degrees, and fractional credits are indicated. The approximate score is derived by grading each drawing on the following basis:

RECTANGLE

		Number	*Relative Length*
Top lines:	outer	1	1
	inner	1	1
Left:	outer	1	1
	inner	1	1
Bottom:	outer	1	1
	inner	1	1
Right:	outer	1	1
	inner	1	1
Upper cross line		1	1
Lower cross line		1	1
	Total	10	10

TRIANGLE

		Number	*Relative Length*
Bottom:	outer	1	1
	inner	1	1
Left:	outer	1	1
	inner	1	1
Right:	outer	1	1
	inner	1	1
Vertical:	left	1	1
	middle	1	1
	right	1	1
	Total	9	9

To illustrate: If *S* draws 4 lines in the outer top line of the rectangle, he is credited with 1 point; if the lines are of the same relative length as those in the figure, he is credited with another point, and so on.

Report your score for the 6 trials, and find the average; also report the average for the class summary blank for the description of the group.

Trial	*Rectangle*	*Triangle*
1	....	....
2	....	....
3	....	....
4	....	....
5	....	....
6	....	....
Subject mean:	....	....
Group mean:	....	....
Group SD:	....	....

Interpretation. 1. Is the recall of a pattern the same process as the recall of verbal elements? Describe the process.

2. Plan a similar experiment for another sense organ.

CHAPTER 11

Affective Reactions: Feelings and Emotions

The usual experiments on the topic of feelings and emotions deal either with the preferences that subjects show for objects about them, such as colors and forms, or with certain expressions of the subject when he is experiencing an emotion or a feeling. Under the heading of expressions of the subject such facts as change in rate of heart beat or of respiration are investigated. The change in electric resistance of the body during different reactions is receiving attention. The experimental determination of the subjects' preferences for colors will serve to illustrate the impression method of studying the problem.

EXPERIMENT 49.—AFFECTIVE QUALITIES OF COLORS

Problem. To determine the relative pleasantness of different colors, with their shades and tints, and of the colors in combination.

Materials. Color squares uniform in size (about 1 square inch). The basic colors with their shades and tints, and the colors in combination, should be represented. The experiment is given successfully to groups by means of an opaque projector; the color combinations are prepared on cards.

Procedure. Each color must be compared with every other color. Yellow, for example, is compared in turn with each of the other colors. *S* looks at yellow and the comparison color, and states his preference; the judgments should be made promptly. Consider only the present effect that the color has on you. Enter your judgments in the blank provided.

Check the preferred color on the *horizontal* line. Thus, if yellow is preferred to a tint of green, yellow is given a check on its horizontal line under the green tint. If the red shade is preferred to purple, a check is placed on the horizontal line to the right of *RS* and directly under *PR*. This procedure is continued for all the combinations shown in the blank. The total checks are then added; the color preferred above all others will have 15 checks opposite it. The rank of the other colors will also be shown.

The method used in this experiment is that of *paired comparison*. It is extensively used when ranking instead of measuring is the aim.

Results. Enter in the blank the preference for each pair of colors.

	COLORS								SHADES				TINTS				TOTAL
	Y	B	R	G	OR	PR	BG	GY	Y	B	R	G	Y	B	R	G	
Y																	
B																	
R																	
G																	
PR																	
BG																	
GY																	
OR																	
YS																	
BS																	
RS																	
GS																	
YT																	
BT																	
RT																	
GT																	

Interpretation and questions. 1. Determine from the class results which are preferred: saturated colors, shades, or tints.

2. From introspective reports, determine as far as possible the cause of such preference.

3. Two or three members of the class should combine the judgments of the entire group; this is done by tabulating the number of times that each of the colors was preferred.

4. Find the coefficient of correlation between your own ranking and that based on the combined judgment of the class. Is there a high degree of consistency among the members of the class?

EXPERIMENT 50.—ORGANIC RESPONSES: EMOTIONS

Problem. The experiments on emotions center dominantly about the organic responses that are aroused by certain stimuli. Casual observation will reveal changes in breathing and heart action, but such changes, together with many others, are better observed with special mechanical devices and under controlled conditions. The experiment will reveal some of the techniques in the study of emotional responses.

Apparatus. The student should become familiar with the following pieces of apparatus:

1. The kymograph with smoked paper. The purpose of this is to serve as a recording device. Several responses may be permanently recorded at the same time.

2. The pneumograph. This instrument, when connected with the kymograph, makes a graphical record of changes in breathing.

3. The sphygmomanometer. This is used to measure blood pressure. The stethoscope enables the experimenter, by means of auditory stimuli, to determine the condition of the flow of blood through a particular artery.

The student should note particularly the method of connecting each instrument, by means of rubber tubes, to a kymograph.

Procedure. The effect of stimuli that arouse emotional responses is readily seen on the instruments. The voice or the facial expression of an individual may be controlled, but the more subtle organic changes will continue unchecked. This may be shown for ordinary stimuli that arouse fear or anger. With other indicators—the reaction time apparatus and the association test, for example—it is often possible to demonstrate that the subject knows certain facts that he is attempting to hide. The literature reports many studies of this type, and this literature should be consulted for the detailed procedure. No results are to be recorded.

EXPERIMENT 51.—STUDY OF EMOTIONAL MATURITY

Problem. Growth to maturity includes the training and development of emotional responses, as well as of the other aspects of the individual. The term "personality" is much broader than the concept of emotional maturity, but the two necessarily overlap. The present study aims to introduce rating scales by means of which the individual himself, or others who know him intimately, may isolate significant aspects in the development of his personality.

Materials. A large number of blanks and test forms for the study of the personality have been developed. These have a definite value for the student, even though the experimental methods for the description of the individual remain relatively inaccurate. The Willoughby Emotional Maturity Test and the Bernreuter Personality Inventory, both published by the Stanford University Press, reveal facts significant to the student. The revised form of the Social Intelligence Test by F. A. Moss, T. Hunt, and K. T. Omwake (published by the Center for Psychological Service, Washington, D. C.) examines other aspects of the individual.

Procedure. The instructions accompanying the test are to be followed.

Results. The key for grading the test, and norms for college students, are furnished.

Interpretation. The tests point out a large number of desirable and undesirable responses of people. The results are to be used for the student's own guidance rather than for comparative purposes in a class.

CHAPTER 12

The Individual in Larger Tasks

The final problems of the individual center about his participation in certain larger tasks and about the particular nature of the individual himself when considered as a whole. We do not abruptly break away from the analytical studies of the earlier experiments, but rather view these in their relation to general efficiency, to the nature of the behavior in certain prescribed situations, to the ability to persist in a task, and so on for other aspects of daily living.

EXPERIMENT 52.—MEASUREMENT OF INTELLIGENCE

Problem. To measure the intellectual level of the members of the experimental group.

Materials. A standardized intelligence test for each student; watch. Choice must be made among a number of tests. If the Army Alpha is selected, the form revised by E. O. Bregman will probably give better results for college students than the original form. This test is published by the Psychological Corporation of New York City. The Henmon-Nelson Tests of Mental Ability, published by Houghton Mifflin Company, are widely used. The American Council Psychological Examination makes comparisons among different colleges possible; the examination is issued by the American Council on Education, Washington. D. C.

Procedure. The directions accompanying the test are to be followed.

Results. The blanks are to be scored by means of the key, and your record entered in the proper blanks.

Interpretation. 1. Norms are included with the data on the test, and you may determine your percentile position by consulting this material.

2. To be of value, any test for measuring intelligence must be carefully standardized. This means that it must have been tried out on known keen and dull individuals, and the scores reached by different grades of ability carefully determined. The scores gained from subsequent testing mean that the individual falls within some group tested formerly—the keenest. the average, just below the average, and so on.

3. Is a high level of intelligence required for all school subjects? for all useful activities in life?

4. Many progressive schools know the intelligence level of their students. In what way could this information be useful to teachers and parents?

5. Is there danger in telling people about their intelligence rating, particularly if it is low?

6. Chapter 1, "Binet's scale for measuring general intelligence," and chapter 2, "Army Alpha and the rise of group tests for measuring intelligence," in Garrett's *Great experiments in psychology,* trace the development of the intelligence testing movement.

EXPERIMENT 53.—MEASUREMENT OF ART CAPACITIES

Problem. To measure the ability of subjects to judge the merit of art objects.

Materials. Two standardized tests in this field will be given: (1) the Meier-Seashore Art Judgment Test; and (2) the McAdory Art Test.

Procedure. Instructions accompany each of the tests. In the Meier-Seashore test pictures are presented in pairs. The two pictures are alike except in one particular. Read the brief description of each pair of pictures, and give your judgment as to which picture is the better. In your report, write *L* if you prefer the picture on the left, and *R* if you prefer the one on the right. After all in the experimental group have taken the test, a key will be supplied for checking the right answers.

In the McAdory test, note the description of each plate, and the particular characteristic for which each is to be judged. Give the order in which you rank the four illustrations on each plate. The correct order will be given after all the subjects have completed the test.

Results. Enter the scores for the tests in the proper blanks.

	Score	*Blank*
Meier-Seashore Test	....	....
McAdory Test	....	....

Interpretation. 1. Norms are given for both tests; in the personal data blank, give your position in the adult population.

2. Find the coefficient of correlation between the two sets of scores obtained from the class. Do the two tests measure the same capacity?

EXPERIMENT 54.—EFFECT OF PROLONGED WORK

Problem. For certain problems it is important to know in quantitative terms the effect of prolonged work in an activity. Subjective estimates of fatigue or of monotony are not reliable. This experiment will investigate the quantity of work, and its accuracy, at different periods during a prolonged task.

Materials. Blank in appendix B; watch.

Procedure. The blank is arranged to provide for a large number of exercises in multiplication. Four successive figures are to be multiplied, but attention is to be given only to the unit figures in the answers. For example, in the column of figures at the left, the subject will proceed as follows:

		Exercise	*Answer*
$3 \times 9 = 27$	The 2 is neglected	3	
$7 \times 2 = 14$	The 1 is neglected	9	
$4 \times 7 = 28$	The 2 is neglected;	2	
	record 8 for the answer	7	8
		4	4
Now begin with 9 and proceed as follows:		5	0
$9 \times 2 = 18$	The 1 is neglected	8	6
$8 \times 7 = 56$	The 5 is neglected	3	8
$6 \times 4 = 24$	The 2 is neglected;	6	6
	record 4 for the answer		

The process beginning with 2 is identical.

Now begin with 7, and proceed as before, with the exception of the 0 answer, which will introduce a slight change.

$7 \times 4 = 28$ The 2 is neglected
$8 \times 5 = 40$ The 4 is neglected, but for further multiplying take the 0 to be 7
$7 \times 8 = 56$ The 5 is neglected; record 6 for the answer

The process is continued for the entire column. Do not carry the multiplications from one column to the next—each is independent. Note especially that when 0 is an answer it is so recorded, but when it is to be used for further multiplying, 7 is always substituted for it.

S should work steadily and give his best efforts. If the figures in the column are followed with the left thumb, the beginning of the four figures for multiplying will always be readily seen. After every minute of work *E* will give a signal, and *S* is to encircle the last answer written. This must be distinctly done, since interpretation of the results is impossible unless

the amount done during each period is known. The test should be continued for at least 40 one-minute periods; the more significant aspects of fatigue are revealed only after many hours or days of continuous work.

Results. Report the number of exercises worked in each of the periods. The errors are to be found by checking the subject's answers against the right answers.

Interpretation. 1. Combine the scores for the different members of the class into a composite score, and represent this graphically.

2. Graph your own record with that of the class.

3. At what stage of the work are you relatively the best? the poorest? Is your performance seriously affected by continued work?

4. What evidence of fatigue or monotony does the curve of work show?

5. Does the curve show evidence of learning?

6. May the facts brought out in the experiment constitute an important difference among individuals? Illustrate.

Supplementary experiments. The study of the errors during different periods of work is often revealing. The time of the experiment should be lengthened for most results of fatigue.

Part III

VARIABLE RECORDS: THEIR NATURE AND THE METHODS OF USING THEM IN SCIENTIFIC INVESTIGATIONS

General impressions are never to be trusted. Unfortunately, when they are of long standing they become fixed rules of life, and assume a prescriptive right not to be questioned. Consequently, those who are not accustomed to original inquiry entertain a hatred and horror of statistics. They cannot endure the idea of submitting their sacred impressions to cold-blooded verification. But it is the triumph of scientific men to rise superior to such superstitions, to desire tests by which the value of beliefs may be ascertained, and to feel sufficiently masters of themselves to discard contemptuously whatever may be found untrue. (*Francis Galton.*)

There was about Ebbinghaus a sort of masterfulness; he never did violence to the facts, but he marshalled them; he made them stand by and deliver; he took from them as of right all that they contained, and with the tribute thus exacted he built up his theories and his system. (*Edward Bradford Titchener, in* American journal of psychology, *vol. 21, 1910, p. 405. By courtesy of the publisher.*)

CHAPTER 13

The Nature of a Human Record of Performance

A previous chapter discussed the fact that we have a twofold interest in human responses. At one time we ask: What are the reactions like? Is the behavior in the vocal cords or in the glands? Is the awareness a kind of nausea or a kind of blue or sweet? At another time we ask: How strong is the reaction? With what force do the vocal cords respond? How intense is the nausea or the blue? Experiments on the former questions give qualitative records, and on the latter quantitative. The nature of the quantitative record will be investigated in this chapter.

The nature of the quantitative record of performance. A person's record for making crosses for periods of 30 seconds was found; the following scores were received in ten trials: 63, 69, 65, 72, 64, 68, 64, 65, 70, 66.

These figures reveal a fundamental fact which applies to all records of human performance: the records are variable. Of the ten scores, only two are alike, and these do not succeed one another. The difference between two successive records is as much as 8 items, which represents a change of over 11% in the performance.

The possibility of dealing scientifically with variable records. For many years it was believed that the variable nature of human performance precluded the possibility of using human records in scientific work. The older scientist trained in the accurate determination of constant quantities, gave expression to his best training when he questioned the conclusions in a field that laid its foundation on quantities which fluctuate from one observation to the next, which are different today from what they were yesterday, and which will change again tomorrow. Accordingly, it is necessary to show how variable records can be used to describe a fact accurately, and how they can be made the basis of a science.

Human records show regularity. Examination of a large number of human records will show that even though they are variable, they are regular. The performance of persons, if carefully determined, gives four basic types of records. The most common record is that which shows gradual improvement. There may be scores that are lower than those that precede them—that is, the progress will be irregular—but the scores

as a whole will show an unmistakable increase in size. This type of performance is found in the experiments on learning. A second type of record for an individual will show a gradual decrease in the size of the scores. A weekly test, during the summer vacation, on rate and accuracy in the fundamental operations, would in all probability give this result. The performance here is again irregular, but within the irregularities there is a gradual decrease in the amount accomplished and in its accuracy. This type of record is discussed in the experiments dealing with fatigue and forgetting. A third type of performance has the characteristic often ascribed to all human records—that of being haphazard. A person's record that is based entirely on guessing will show irregularity and inconsistency. Thus, if a person attempts to guess numbers drawn from a box, the result will be a collection of scores that fluctuate without a plan; large and small errors will alternate, one individual will do as well as another, and any attempt to make a prediction in such a performance will in itself be a guess. In the study of human behavior no use is made of this type of record.

Finally, as a fourth type of record, we find the scores which remain relatively stationary in their level, and which at the same time fluctuate from trial to trial. The distance at which the ticking of a watch can be heard illustrates this record. A careful examination of a large number of scores for an individual shows that the distance varies from trial to trial. Unlike the chance performance, however, the scores are regular and conform to a plan.

This regularity can be seen in the following table, which gives the number of additions completed by a subject in 183 one-minute trials.

Table 1.—Number of Additions of Two Digits Completed in One Minute

Number Completed	*Frequency*	*Number Completed*	*Frequency*
61	1	69	19
62	5	70	15
63	9	71	15
64	10	72	14
65	14	73	10
66	18	74	7
67	24	75	2
68	20		
		Total	183

The first fact to be observed is that the scores tend to *gather about some central performance*. In this case the center about which the scores gather is near 67 or 68. Further, the number of records that differ from this

central score *becomes progressively fewer* as the scores become increasingly larger or smaller than the central score. This holds true in every case, with the exception of the scores 70 and 71, which were made with equal frequency. If the test were continued, it would probably be found that 70 additions were made more often during the minute than 71. It should be noted that the smallest score occurs only once, and the largest twice. The observer can be quite positive—and it is in this respect that the human performance record differs from the fortuitous results growing out of chance—that future scores will center about 67 and 68, and that the extreme scores will fall very infrequently outside the limits of 61 and 75.

This regularity and consistency in the performance of an individual is so significant that it has been studied extensively as a problem in itself worth while, and it has been made the basis for detailed inquiries into human behavior. Technically, such a record from an individual is known as a *frequency distribution.* Its nature can best be seen when the records are shown in a graph. If the scores are represented on a horizontal line, and the frequency of their occurrence on a vertical line, a bell-shaped curve like that in Figure 1 will result.

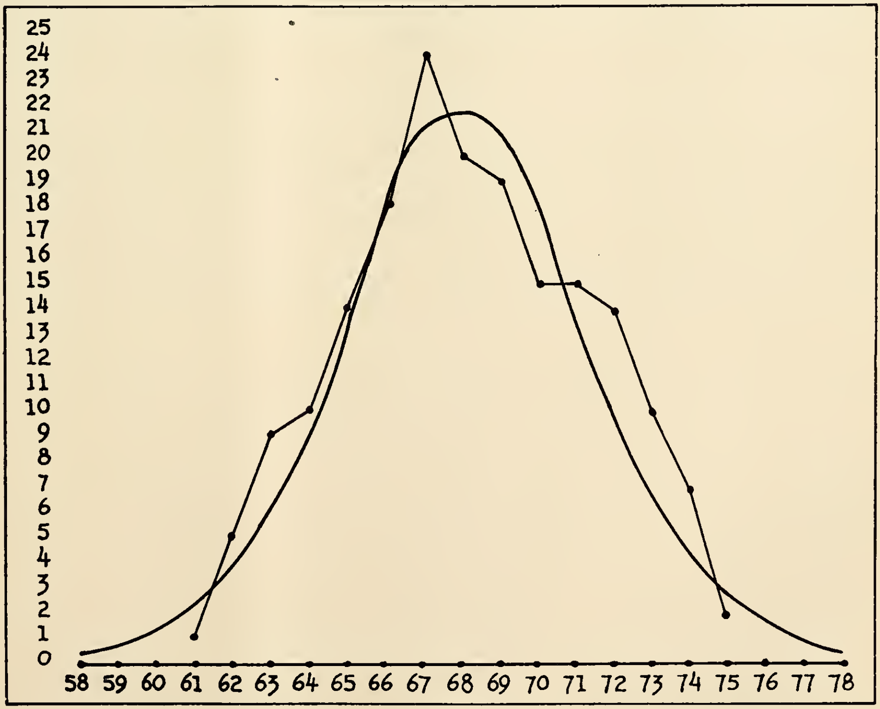


Figure 1.—Distribution of scores in adding (Table 1) and ideal frequency curve approximated by performance.

As the number of scores is increased, the graph becomes more nearly uniform in its contour. It tends to approach the ideal representation shown in the curved line. Such a graphical representation is known as the *normal curve,* the *normal frequency curve,* or the *normal probability curve.* The figure with straight lines is known as the *frequency polygon.* Many of the calculations regarding human performance are based upon the assumption that records tend to be distributed in the manner here shown.

Two types of records combined. Frequently, the records for an individual show the general distribution here described, together with a general tendency to improvement in the scores (or the reverse), or a distinct tendency to periods of high and again of low efficiency. A performance with the scores dominantly large or small is called *skewed.* The graph for the additions shows a slight tendency to skew toward the higher scores; this may probably be accounted for by the fact that the individual had not reached his maximum efficiency at the beginning of the test. The skewness in this case is negative; concentration of scores at a low figure would be positive. Tasks continued after fatigue has set in often result in a record that is skewed toward the lower scores. Occasionally we find an individual who at one period makes very high scores and at another low scores, but with each performance consistent. The performance during summer and winter would conceivably show this *bi-modal* distribution, as it is technically called. This type of performance has been found in children who are sickly; they show one type of performance during the days of lowered vitality, and a different one during periods of normal health. The point to be stressed here is that in spite of variations and modifying conditions, the performance of an individual is *regular* and the measurements made of it will give dependable knowledge of the individual.

Causes underlying the variability in human performance. The accurate description of records has led to inquiry into the causes of human variability, and also to examination of the fact that human records tend to center about some central point. From such studies it appears that each person has a type of reaction that is as characteristically his own as is a structural fact, such as height or lung capacity. This reaction may be changed, within limits, to bring about a better or a poorer performance. Relatively permanent changes result from such processes as maturing, conditioning, learning, and the changes associated with decline in old age. Momentary fluctuations in performance are due to changes either in the environment or within the organism itself. That is, the capacity to react is constant in a given individual, but it is affected by a large number of factors—interfering sounds, changing intensities of light, moving objects, the ceasing of certain stimulation to which the organism has become adapted, the increasing or the languishing of certain motives, modifications in

metabolism, a lowered rate in the heart beat, the changes that come with fatigue, and so on almost endlessly.

In this consistency yet infinite variability of behavior, the individual is like other realities in nature, which in themselves appear constant but which are modified by many conditions. The daily flow of sap in a tree, the annual growth of the tree, the yield of crops, the amount of honey stored by a hive—all show this tendency to definite type, with variability among the different measurements. Continued measurements of these will show the normal curve of distribution which was found for the performance in adding. The human being is unique in the nature of many of his responses, and also in the conditions that modify them; he conforms to a general plan in revealing a typical mode of response which is influenced by many conditions.

Scores from a group in form of normal distribution. The preceding paragraphs describe the general nature of the performance of an individual, and the possibility of measuring this in a way to be made the basis for an accurate description of the individual. An important extension of the facts stated is that the scores for a group of homogeneous individuals show the same distribution of scores that was found for the individual; that is, the scores for the individuals of a group are distributed in accordance with the normal frequency curve. This could be shown by measuring the height of men, by testing the spelling ability of eighth-grade pupils, by determining the number of crosses that an adult group can make in 30 seconds, or by group measurements in many other fields. The results given for some of the experiments in preceding chapters are distributed in the form of the normal curve. The individuals vary among themselves in the manner shown for the many scores of one person, and the scores for the group center about a common score, as was shown for the individual. This fact regarding groups is of fundamental significance, since it makes possible the measurement of a group as well as that of an individual.

Certain limitations will become apparent when the problem of measuring a group is more carefully considered. It is obviously necessary to limit the group which is being measured. A mixed group of men and women, of the aged and the immature, without regard to the proportions of each, may well give a group score that is identical with the guessing performance described earlier. A group in which the keener individuals dominate will be skewed to the upper end of the distribution, and, conversely, a group in which they are outnumbered will give a record which is skewed to include many small scores. This record from the group is not identical with the many records of any one member of the group: the two may be different in the general level about which the scores cluster, and also in the extent to which they vary from this general level. The in-

dividual and the homogeneous group are alike, however, in that both give records which are concentrated at some central point, and which deviate gradually from this central score.

It should be noted, finally, that many questions on the nature of the performance record remain unsolved; some performances may not be describable in terms of the normal distribution curve, and some may be skewed to such an extent that a description in the terms used for the normal distribution will not represent them accurately. The problems here suggested belong to advanced courses in the field.

Questions and Topics for Discussion

1. Do the grades received by an individual tend to center about some general level? Is there some regularity in the extent to which they vary from the central score?

2. What justification is there for distributing the grades for a body of students so that a limited per cent will receive a particular grade?

3. Report on the nature of the Gaussian curve, and relate it to the discussion in this chapter. (For students in mathematics.)

4. Each individual has a performance record which is true to his nature until he is in some way changed. Discuss.

5. Account for the fact that the performance of a student often appears to be entirely different at one period of the year from the performance at another period. In a case like this, how should the measurement of a performance be made, in order to be valid?

6. How do we characterize people when we have in mind primarily the general level of their performance?

7. How do we characterize people when we have in mind the variability in their behavior?

CHAPTER 14

How to Record the Scores of a Performance

Although in this course the dominant emphasis is placed upon the collecting and interpreting of facts about human responses, a chapter should be devoted to the manner of recording data. The measures, when stated in their original form, are often difficult to comprehend, and still more difficult to interpret. With the growth of the science, a number of meth-

Table 2.—Record of Adult Subject for Making Crosses for Periods of 30 Seconds

Trial	*Score*	*Trial*	*Score*	*Trial*	*Score*	*Trial*	*Score*
(1)	66	(26)	67	(51)	60	(76)	65
(2)	58	(27)	75	(52)	70	(77)	66
(3)	64	(28)	58	(53)	76	(78)	58
(4)	59	(29)	68	(54)	76	(79)	58
(5)	64	(30)	78	(55)	75	(80)	68
(6)	67	(31)	70	(56)	70	(81)	67
(7)	65	(32)	72	(57)	77	(82)	70
(8)	67	(33)	70	(58)	68	(83)	70
(9)	65	(34)	67	(59)	65	(84)	74
(10)	66	(35)	67	(60)	69	(85)	76
(11)	66	(36)	65	(61)	61	(86)	66
(12)	62	(37)	69	(62)	68	(87)	71
(13)	68	(38)	68	(63)	83	(88)	73
(14)	64	(39)	74	(64)	71	(89)	78
(15)	64	(40)	79	(65)	68	(90)	69
(16)	77	(41)	69	(66)	72	(91)	72
(17)	63	(42)	82	(67)	63	(92)	80
(18)	79	(43)	72	(68)	71	(93)	70
(19)	70	(44)	80	(69)	74	(94)	72
(20)	66	(45)	66	(70)	71	(95)	71
(21)	73	(46)	83	(71)	68	(96)	71
(22)	74	(47)	78	(72)	67	(97)	77
(23)	77	(48)	83	(73)	65	(98)	78
(24)	63	(49)	73	(74)	79	(99)	75
(25)	63	(50)	72	(75)	67	(100)	76

ods for recording facts, with a view to making them intelligible, have been developed. Succeeding pages will describe some of the principal methods in use.

Measures in their original form. The figures in Table 2 represent the number of crosses made by a student in 100 trials of 30 seconds each.

For certain purposes the measures should be retained in the form here given. For example, a study of the change in scores from trial to trial will require the data in the original order. For most purposes, however, a rearrangement of the scores will give a clearer description and lead to a truer interpretation of the performance.

Measures given in order of size. Viewing a large number of scores as a whole is facilitated if the scores are recorded in the order of their size rather than in the order in which they occurred. The best score should be placed first, and this should be given the highest number in the series. For results expressed in time required to complete a task, or in number of errors made, the best score is the smallest. A column arrangement is preferred. The original scores are given below in the order of their size.

TABLE 3.—SCORES FROM TABLE 2 GIVEN IN THE ORDER OF THEIR SIZE

Order	*Score*	*Order*	*Score*	*Order*	*Score*	*Order*	*Score*
(100)	83	(75)	74	(50)	70	(25)	66
(99)	83	(74)	74	(49)	69	(24)	66
(98)	83	(73)	74	(48)	69	(23)	66
(97)	82	(72)	73	(47)	69	(22)	65
(96)	80	(71)	73	(46)	69	(21)	65
(95)	80	(70)	73	(45)	68	(20)	65
(94)	79	(69)	73	(44)	68	(19)	65
(93)	79	(68)	72	(43)	68	(18)	65
(92)	78	(67)	72	(42)	68	(17)	65
(91)	78	(66)	72	(41)	68	(16)	65
(90)	78	(65)	72	(40)	68	(15)	64
(89)	78	(64)	72	(39)	68	(14)	64
(88)	77	(63)	72	(38)	68	(13)	64
(87)	77	(62)	71	(37)	67	(12)	64
(86)	77	(61)	71	(36)	67	(11)	63
(85)	77	(60)	71	(35)	67	(10)	63
(84)	77	(59)	71	(34)	67	(9)	63
(83)	76	(58)	71	(33)	67	(8)	63
(82)	76	(57)	71	(32)	67	(7)	62
(81)	76	(56)	70	(31)	67	(6)	61
(80)	76	(55)	70	(30)	67	(5)	60
(79)	75	(54)	70	(29)	66	(4)	59
(78)	75	(53)	70	(28)	66	(3)	59
(77)	75	(52)	70	(27)	66	(2)	58
(76)	74	(51)	70	(26)	66	(1)	58

The measures grouped. The most common way of recording a long series of scores is to group them. The grouping is done in different ways. The method shown in Table 4 preserves the exact value of each score; this is the method most generally used, unless the range of scores is very large.

TABLE 4.—SCORES FROM TABLE 2 GROUPED

Score	*Frequency*	*Score*	*Frequency*
83	3	70	7
82	1	69	4
81	0	68	8
80	2	67	8
79	2	66	7
78	4	65	7
77	5	64	4
76	4	63	4
75	3	62	1
74	4	61	1
73	4	60	1
72	6	59	2
71	6	58	2
		Total (N)	100

The term *frequency,* which means the number of scores in each class interval, or the frequency with which the scores occur, is designated by the letter f. The total number of scores in all the intervals is represented by N.

Often the scores of a certain interval are grouped, in order to condense the record. Thus, the facts might be shown in class intervals of 5: from 80 to 84 for the highest, 75 to 79 for the next, and so on.

The limits of these class intervals must be very carefully indicated. Several ways of doing this are unmistakable in their meaning. The method shown in the preceding paragraph is in common use. The figures indicate that the highest interval begins with 80 and ends with 84; since the highest interval begins with 80, it is fairly clear that all fractional scores between 79 and 80 (79.8, for example) will be included with the interval 75-79. However, when the limits are written in the form 75-79.9, it is unmistakable that any score from 75 up to any amount less than 80 is included in this interval. The figure 79.9 means 79.9 . . . ; it does not change the range of the interval to less than 5, but locates definitely the fractional scores between 79 and 80. Some studies give the intervals in round numbers, as 75-80 and 80-85; this method is generally clear, but it may lead to the error of including scores of 80 with either of the class in-

tervals. At times only the lower score is used, with a dash after it, as 75—, 80—, and the like; the figure 75— means 75-79.9.

The size of interval to use depends on several factors. The principal consideration is that the original significance of the scores be not distorted. It is well to use from 10 to 20 steps, and any size to give this is to be preferred. Obviously, intervals such as 2, 3, 5, 10, and 25, will be chosen in preference to others near this size. The limits should fall at naturally accepted divisions of the number scale; thus, if the interval is 5, at 15, 20, 25, and other numbers divisible by 5; if 3, at 9, 12, 15, and so on.

The original data are represented below in class intervals with a range of 2.

TABLE 5.—DATA OF TABLE 3 IN GROUPS WHICH INCLUDE AN INTERVAL OF TWO SCORES

Scores	*f*
82—83.9	4
80—81.9	2
78—79.9	6
76—77.9	9
74—75.9	7
72—73.9	10
70—71.9	13
68—69.9	12
66—67.9	15
64—65.9	11
62—63.9	5
60—61.9	2
58—59.9	4
N......	100

Measures represented by means of a graph. Frequently, data become meaningful only when they are shown graphically. The figures are represented by distances or by areas. Many forms of graphs have been devised, and several in common use in psychology will be described in succeeding paragraphs. The type of graphical representation that should be made depends upon the purpose for which the facts are to be used.

The work curve. One of the large problems in psychology is to trace the progress that an individual makes in a given task. This can be shown more clearly in graphical form than by means of figures alone. To illustrate the process, the original data on making crosses will be shown as the experiment progresses from the beginning of the task to the end. Since our interest is not in minor fluctuations but in general progress, the data can best be represented in 20 steps, each of which is the average of 5 scores.

The size of the score is represented on a vertical line; the number of the trial on which the score was made is represented on the horizontal base line. A dot is now placed for each score, directly above the trial in which it came and at the level of the figure representing the size of the score. Thus, the average of the first 5 scores is 62. To represent this a dot is placed directly above the figure 5 on the base line and level with the figure 62. The average of the 5 scores between 25 and 30 is 69. The score is represented by a dot level with 69 and directly above the figure 30.

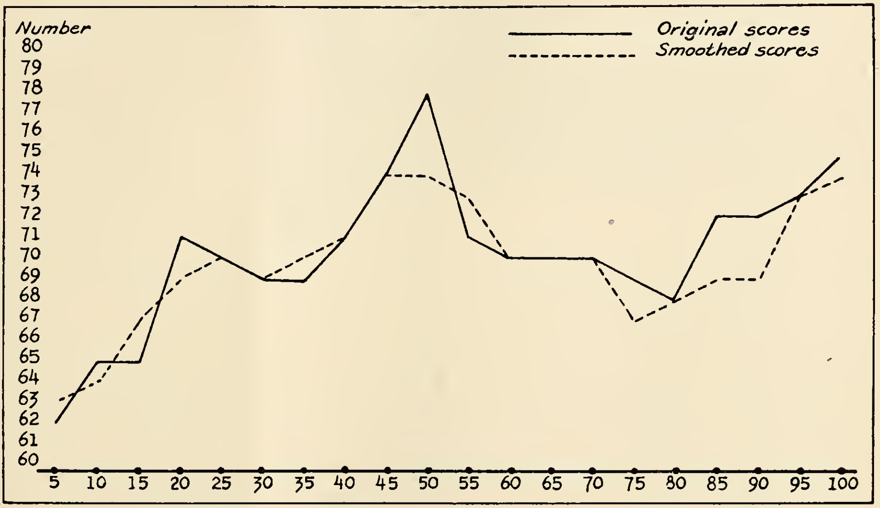


Figure 2.—Graph representing data of Table 6.

A line should be drawn through the dots to complete the curve. The graph for the data on crosses is shown in Figure 2. The averaged scores on which the graph is based are given in Table 6.

Smoothing the curve. Curves which show the exact scores will often fluctuate widely for successive trials. Such minor fluctuations are not important when the progress as a whole is being studied. The general nature of the performance is better represented by a relatively smooth line which does not touch the extreme points. A common method of smoothing a curve is to represent the score for any trial by the average of three scores—the score on the trial in question, the one preceding it, and the one following it. Thus, the fourth score in Table 6, which in the original record is 71, becomes, when smoothed, the average of 65, 71, and 70, or 68.7. To smooth the first score, the first score is counted twice and averaged with the second; in the table the smoothed score is the average of 62, 62, and 65, or 63. In the same way the last score is taken twice, and added to the score which precedes it, to give a smoothed final score;

for the figures in the table the smoothed score is the average of 75, 75, and 73, or 74.3. The last column of Table 6 gives the smoothed scores for the distribution. These are represented graphically by the dotted line in Figure 2.

TABLE 6.—SCORES FROM TABLE 3 AVERAGED IN GROUPS OF 5 AND SMOOTHED (Figures Given to Nearest Whole Number)

Serial Order of Scores	*Average of Five Scores*	*Scores Smoothed*
1— 5	62	63
6— 10	65	64
11— 15	65	67
16— 20	71	69
21— 25	70	70
26— 30	69	69
31— 35	69	70
36— 40	71	71
41— 45	74	74
46— 50	78	74
51— 55	71	73
56— 60	70	70
61— 65	70	70
66— 70	70	70
71— 75	69	67
76— 80	63	68
81— 85	72	69
86— 90	72	72
91— 95	73	73
96—100	75	74

The bar diagram. Certain performance records show their meaning most clearly when the scores are represented by lines or bars drawn to lengths which correspond to the sizes of the scores. A graphical representation so made is a *bar diagram.* In its construction it is well to consider first the largest number in the performance, and from that determine the length that may be used to represent a given number of units; the size of the paper generally fixes an arbitrary limit on the proportions that may be employed. Suppose the largest unit to be represented by a bar is 15. A convenient length for each unit would be ¼ inch. Accordingly, the bar for the first 15 units would be drawn 3¾ inches long. The first frequency of 4 would be represented by a bar 1 inch long, the second of 2 by a bar ½ inch in length, and so on for the other numbers in the distribution. Figure 3 shows a tabulation of scores and their representation by means of a bar diagram.

Sometimes two units can be represented advantageously on the same bar, with different shading. Thus, the average biweekly score of a class, on a standardized arithmetic examination, gave the results which are represented both in figures and on a bar diagram in Figure 4.

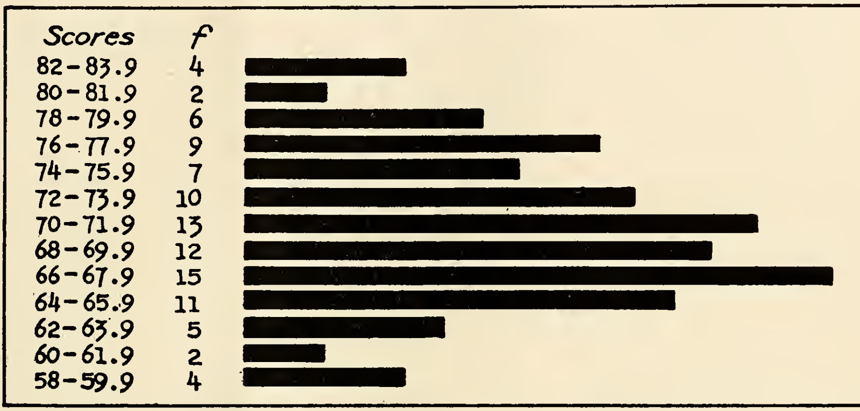


Figure 3.—Table 6 represented as a bar diagram.

The histogram, frequency polygon, and frequency curve. The method used in constructing the bar diagram is employed also in constructing the *histogram,* the *frequency polygon,* and the *frequency curve.* In the histogram, vertical lines are drawn at each of the class limits, to a height which

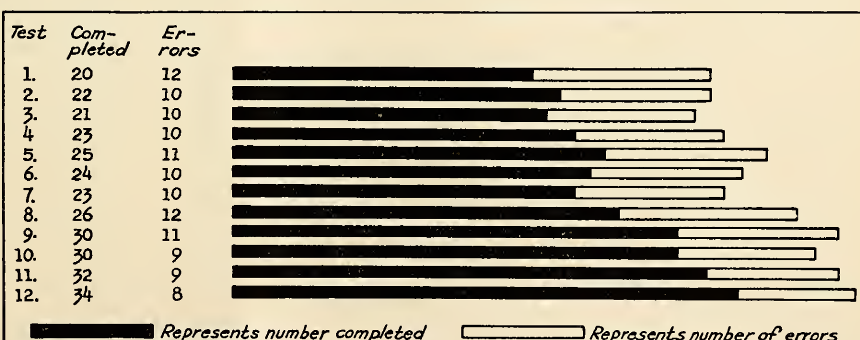


Figure 4.—Bar diagram to show the average number of exercises completed and the average number of errors made by a class on a standardized test in arithmetic.

represents the number in the class. A cross line is drawn between the two lines at the top, to form a rectangle. The rectangles are joined instead of being separated by spaces as in the bar diagram. The distance to represent the number of cases or scores in each class limit is always drawn

vertically in the histogram. The frequency polygon is derived from the histogram by placing a dot at the midpoint of the higher horizontal line in each rectangle, and then connecting the dots with straight lines to form a many-sided figure. A continuous line connecting the dots gives the frequency curve.

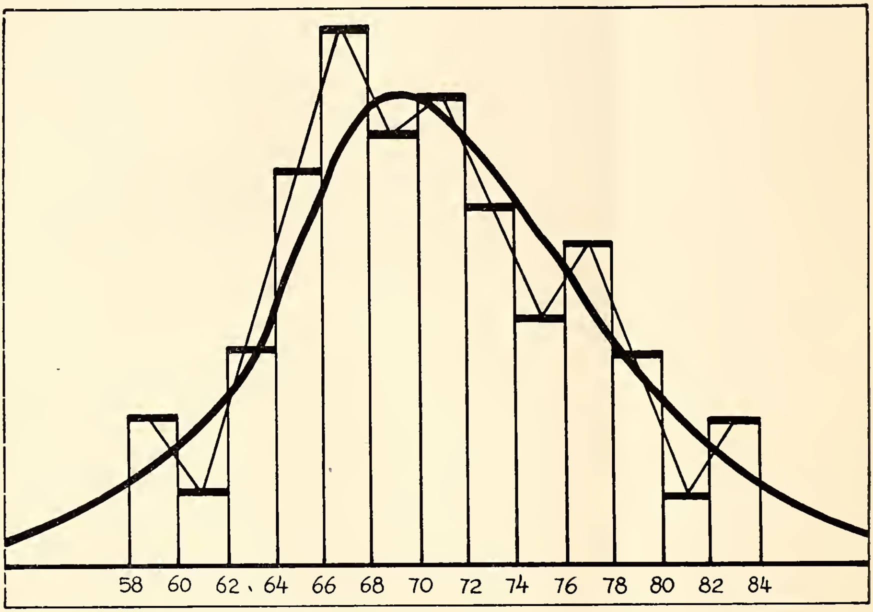


Figure 5.—Table 5 shown as a histogram, a frequency polygon, and a frequency curve.

The original data on making crosses in Table 5 are shown in Figure 5 as a histogram, a frequency polygon, and a frequency curve.

Exercises

The data from the experiments will normally give sufficient material for drill in tabulation and graphical representation. Several exercises are added, so that the entire class may have the same set of figures for the discussion of the methods that should be used.

1. The figures below are the scores in a multiplication test, for successive two-minute periods. Graph the data to show the progress in the task. Smooth the curve.

16, 15, 13, 11, 19, 17, 16, 15, 12, 14, 12, 14, 13, 19, 10, 18,
14, 22, 16, 15, 17, 16, 13, 18, 14, 17, 16, 15, 17, 22, 20, 21.

2. Represent the following distribution of scores in the form of a bar diagram, a histogram, a frequency polygon, and a frequency curve:

Series A

Scores	*f*
0— 1.9	43
2— 3.9	95
4— 5.9	106
6— 7.9	110
8— 9.9	83
10—11.9	55
12—13.9	19
14—15.9	13
16—17.9	7
18—19.9	5
20—21.9	2
22—23.9	1
24—25.9	1
N	540

Series B

Scores	*f*
6— 8.9	2
9—11.9	5
12—14.9	0
15—17.9	7
18—20.9	10
21—23.9	18
24—26.9	23
27—29.9	21
30—32.9	24
33—35.9	20
36—38.9	16
39—41.9	18
42—44.9	14
45—47.9	9
48—50.9	6
51—53.9	2
54—56.9	3
N	198

Series C

Scores	*f*
4— 7.9	12
8—11.9	11
12—15.9	16
16—19.9	22
20—23.9	22
24—27.9	24
28—31.9	26
32—35.9	23
36—39.9	20
40—43.9	15
44—47.9	17
48—51.9	12
52—55.9	13
56—59.9	9
60—63.9	10
64—67.9	8
68—71.9	7
N	267

3. The following are the weekly scores of a child for a test based on the 45 combinations in addition. Show the progress graphically, both for the original and the smoothed curves.

8, 11, 13, 12, 14, 14, 17, 18, 19, 20, 20, 19, 19, 23, 25, 28, 26,
25, 27, 28, 29, 30, 30, 30, 31, 36, 37, 37, 30, 39, 40, 38, 42.

CHAPTER 15

Describing a Variable Record: The Problem

A previous chapter discussed the fact that four types of records are found in the performance of people: (1) the increasing; (2) the decreasing; (3) the haphazard record from guessing; and (4) the relatively stationary record that fluctuates about a central score. Of these the record based on guessing is discarded. The increasing and decreasing records present relatively simple problems so far as the present course is concerned; they are discussed briefly in connection with experiments on learning, forgetting, and continuous work or fatigue. However, the type of record that tends to fluctuate about a central score requires fuller treatment.

Our problem is to describe such a record completely or in its entirety, and to do this in terms that will make accurate comparison with other records possible. We can compare two loads by knowing their weights, and two boards on the basis of their dimensions; a way must be found to compare two performance records with equal definiteness. Completeness of description could be attained by giving the exact score in each performance. Thus, the record of James, in Table 7, might be described in a way that could not be misunderstood, by saying that his per cent of correct words at the end of the first week was 90, at the end of the second week, 60, at the end of the third week, 78, and so on for all the seven results.

Need for a more concise description. This would be a complete description of the record, but it would not, for most purposes, be the most serviceable. For example, one could not, with such a detailed description, accurately compare this record with other records. In order to make the comparison of performance records possible, *each record must be described by one figure:* one figure must be found that will represent all the scores in the record. The possibility of doing this, and, roughly, the method by which it is done, will be illustrated with the three brief records in the table.

A general examination of the three records shows that Margaret is the most capable of the three pupils. This comparison is based on the average standing of each; for James the average is 78, for Robert 78, and for Margaret 88. These figures represent the *level of performance,* or the *ability*

TABLE 7.—RECORDS IN WEEKLY EXAMINATIONS OF THREE PUPILS IN A FIFTH-GRADE SPELLING CLASS

James	*Robert*	*Margaret*
90	80	88
60	76	86
78	75	84
68	78	88
96	84	92
66	76	88
88	77	90

of the three pupils, in spelling. Thus, by means of one figure we are able to describe the character of a series of records. Technically, the term *central tendency* is used for the figure which describes the level of the performance. The following chapter will deal in greater detail with the description of the central tendency of variable records.

But the three records are not completely described by giving the average of each. Note especially that James varies much more in his performance than does Robert. The latter has a consistent, dependable record; the former, one that is capricious and unsteady. This calls attention to the second fact that needs to be given in the description of every record: its variability. In a preliminary way it may be said that the record of James varies from 60 to 96, a range of 36; that of Robert from 76 to 84, a range of 8; and that of Margaret from 84 to 92, a range of 8. The range is an extremely crude measure of this variability, but by employing it here the problem is brought concretely before us. More refined methods of describing the variability of a record will be presented in chapter 17. Although Margaret and Robert appear to be equally variable in their spelling performance, it will be found with more accurate methods that Margaret really has the more constant record of the two.

Summary. To describe a record that conforms to the normal probability curve, two facts with regard to it must be given: (1) its central tendency (most commonly given by the average or mean); and (2) its variability (given roughly by the range). These two facts describe the record in such a way that it can be compared definitely with other records. The central tendency of a record is the point in the record about which the scores tend to fall. The variability of a record is the scatter or spread of the scores about its central point.

Questions and Topics for Discussion

1. In which field would you expect a person to have a more uniform performance record:

(*a*) writing *a*'s, or spelling?
(*b*) solving problems in arithmetic, or adding figures?
(*c*) reading narrative material, or walking?

2. In what fields in life would a constant performance be most valuable? a variable performance?

3. Are there limits beyond which a level of performance in certain fields need not be raised? Where is the desired level for spelling? for handwriting?

CHAPTER 16

Describing a Variable Record: The Central Tendency

Three measures needed to describe the central tendency. The endeavor to describe variable records with precision has made necessary more than one method of expressing the general level of the record. The average may serve best for one purpose, but in another problem a different figure may give the more accurate description. Three measures for the level of the performance are in common use: the *arithmetic mean,* the *median,* and the *mode.* The reasons for using different measures and the method of finding each will be discussed in this chapter.

The arithmetic mean (AM) or the mean (M). The term *arithmetic mean,* or simply *mean,* is used to denote what texts in arithmetic commonly call the average. The term average is at times applied to the central tendency, and the new term has always a specific meaning.

Finding the arithmetic mean when every score is given. In simple problems the arithmetic mean is found without difficulty. All the numbers constituting the variable record are added, and the sum is divided by

TABLE 8.—DATA TO ILLUSTRATE HOW THE ARITHMETIC MEAN IS CALCULATED: DAILY EARNINGS OF A NEWSBOY FOR A MONTH

Amount Earned	*f*	*Total Earned*
$2.50	2	$5.00
2.25	2	4.50
2.00	4	8.00
1.75	4	7.00
1.50	6	9.00
1.25	5	6.25
1.00	4	4.00
.75	3	2.25
.50	1	.50
	31	$46.50

$46.50 ÷ 31 = $1.50, the average daily earnings

the number of scores or records. To illustrate: A newsboy earned the following amounts on the seven days of a week: \$2.50; \$2.00; \$2.25; \$1.75; \$1.50; \$2.25; \$3.50. His daily average for the week—the arithmetic mean of his earnings—is \$15.75 ÷ 7, or \$2.25.

The method is illustrated in a slightly more complicated problem with the data of Table 8.

Each of the amounts earned daily is first multiplied by the number of days in which it was earned, to find the total amount earned for those days. These amounts are added to determine the total amount earned during the month, and the sum is divided by the number of days to determine the average daily earnings.

Finding the arithmetic mean in grouped data. When the facts are grouped in the manner shown in Table 5, page 138, a preliminary step is required before the method described in the preceding paragraphs can be used. The process will be illustrated with the data of Table 9.

TABLE 9.—DATA TO ILLUSTRATE THE CALCULATION OF THE MEAN WHEN THE FACTS ARE GROUPED IN CLASS INTERVALS: EARNINGS OF A NEWSBOY FOR 16 DAYS

Amount Earned	*f*	*Total Earned*
\$2.50—3.00	2	\$5.50
2.00—2.50	4	9.00
1.50—2.00	5	8.75
1.00—1.50	3	3.75
.50—1.00	2	1.50
	16	\$28.50

\$28.50 ÷ 16 = \$1.78, the average daily earnings

In this problem the facts are not given completely, and all that we can do is to come as near to the exact mean as possible. Since the earnings were between \$.50 and \$1.00 for 2 days, the closest estimate is that they were \$.75 on each of the 2 days. The total amount earned during the 2 days is, accordingly, 2 × \$.75, or \$1.50. The midpoint of the interval is taken as the most probable amount earned each day. For the interval \$1.00 to \$1.50, the midpoint is \$1.25. Since this was earned for 3 days, the total for this time is 3 × \$1.25, or \$3.75. The calculations for the remaining days are similarly made. The total amount earned is divided by the number of days to find the mean. The mean is, consequently, \$28.50 ÷ 16, or \$1.78.

Although this method appears inexact, the answer is generally very close to the true value. The errors for the different intervals tend to offset or balance one another. This balancing of errors can, however, occur only

when a large number of records is involved; when only a few scores are represented, each should be taken at its exact value.

The median (Med). The arithmetic mean was at one time the only figure used to describe the general level of a variable performance. But the effort to represent facts exactly and in such a way as to contribute to the solution of problems revealed the need for a new measure to describe the central tendency of a distribution.

The need for an additional measure is readily shown by a simple problem. A standardized arithmetic test is given monthly to pupils in the seventh grade; the following, given in order of size, are the scores for two of the pupils:

Pupil A: 89, 88, 87, 85, 85, 83, 70, 69, 4, 0.
Pupil B: 75, 71, 70, 69, 68, 66, 63, 62, 59, 57.

The mean grade for each is 66. But the records do not show equal ability. A supervisor, with no other facts given, would select pupil *A* as the stronger, and would look for some special cause, such as illness or absence from school, to account for the two low scores. *The average does not describe the record accurately.* To select the more able student we should neglect the numerical statement of ability, and base our judgment on other considerations.

It is, however, possible to represent numerically the performance of the two pupils so that a judgment respecting their relative ability, based on figures alone, will be valid. And conclusions must be drawn from definite facts if general impressions are to be displaced. How can this be done?

The midpoint of the scores in each of the two records is taken to represent the ability of the two pupils. For pupil *A* the midpoint lies between 85 and 83, or at 84; for pupil *B*, between 68 and 66, or at 67. The new figures, 84 and 67, give a truer measure of the ability of the two than did 66 for each. The comparison can now be based entirely on figures, thus excluding from the conclusion the effect of general impressions.

Finding the median when every score is given. The *median* is the midpoint of a distribution, or the middle measure. It is found by arranging the scores in the order of their magnitude and counting to a point that places half of the scores above the point and half below it. The median is the middle score in case the number of scores is odd, or the average of the two middlemost scores if the number is even.

A simple exercise will illustrate the finding of the median. Suppose a pupil's scores in a series of tests are 6, 5, 7, 4, 6, 8, 9, 6, 8, 8, and 9. First the scores are arranged in the order of their size, as follows: 9, 9, 8, 8, 8, 7, 6, 6, 6, 5, 4. Since there are **11** scores the middle score is the sixth; counting from either end we find that the sixth score is 7.

An additional score is included in the following series to give an even

number: 9, 9, 9, 8, 8, 8, 7, 6, 6, 6, 5, 4. The median is the average of 7 and 8, or 7½. The median in both of the following series is 6:

9, 9, 8, 8, 7, 6, 6, 6, 5, 4, 4.
9, 9, 8, 8, 7, 6, 6, 6, 5, 4, 4, 4.

Finding the median when the scores are grouped. The following explanation shows the procedure to be followed in finding the median when the scores are grouped.

TABLE 10.—DATA TO ILLUSTRATE THE CALCULATION OF THE MEDIAN WHEN THE FACTS ARE GROUPED IN CLASS INTERVALS: SCORES ARE FROM AN EXAMINATION IN ARITHMETIC

Scores	*f*
90—94.9	1
85—89.9	5
80—84.9	10
75—79.9	14
70—74.9	11
65—69.9	6
60—64.9	1
Total	48

The midpoint of the series has 24 scores on each side ($48 \div 2 = 24$). To find the midpoint, it is necessary to count 24 scores from either end of the distribution.

Beginning with the smaller scores, we count $1 + 6 + 11 = 18$. If we included the next group, we would have $18 + 14$, or 32, which goes beyond the midpoint. To reach the exact point at the middle we need 24—18, or 6 scores, from the group of 14.

We assume that these 14 scores are distributed equally over the range of 5 scores from 75 to 79.9. The sixth paper extends to a point, 6/14 of the total distance above 75. Therefore:

$\frac{6}{14}$ of $5 = \frac{30}{14} = 2\frac{1}{7}$ .... The distance beyond 75 to the midpoint

$75 + 2\frac{1}{7} = 77\frac{1}{7}$ .... The midpoint or median.

The computation from the larger score will give the same result, as may be seen from the following:

$1 + 5 + 10 = 16$............. The number of papers to the group of 14 within which the median lies

$24 - 16 = 8$ .... The number of papers to use from the group of 14 to reach the midpoint

$\frac{8}{14}$ .... Represents the part of the distance of 5 grades ($80 - 75 = 5$) that needs to be traversed to reach the midpoint

$\frac{8}{14}$ of $5 = 2\frac{6}{7}$ .... The distance below 80 to the midpoint

$80 - 2\frac{6}{7} = 77\frac{1}{7}$ .... The midpoint or median.

If the number of scores is odd, the median is found by the same method. Suppose that the group from 70 to 74.9 has 12 scores instead of 11. The total number of scores is now 49; $49 \div 2 = 24\frac{1}{2}$, the distance to the midpoint or median.

Counting from the smaller score, $1 + 6 + 12 = 19$.

$24\frac{1}{2} - 19 = 5\frac{1}{2}$ .... The distance to go into the group of 14

$$\frac{5\frac{1}{2}}{14} \text{ of } 5 = \frac{27\frac{1}{2}}{14} = \frac{55}{2} \times \frac{1}{14} = \frac{55}{28} = 1\frac{27}{28}$$

$75 + 1\frac{27}{28} = 76\frac{27}{28}$ .... The median.

Counting from the larger score, $1 + 5 + 10 = 16$.

$24\frac{1}{2} - 16 = 8\frac{1}{2}$ .... The distance to go into the group of 14 to reach the midpoint

$$\frac{8\frac{1}{2}}{14} \text{ of } 5 = \frac{42\frac{1}{2}}{14} = \frac{85}{2} \times \frac{1}{14} = 3\frac{1}{28}$$

$80 - 3\frac{1}{28} = 76\frac{27}{28}$ .... The median.

This method of locating the exact position in a group should be clearly understood, since the same method is used later in finding deciles, quartiles, and other fractional parts of a distribution.

The mode. The mean and the median are used in most of the problems that require a measure of the central tendency. For certain purposes, however, a third measure, known as the *mode,* is the most accurate. The mode is the most common score. In everyday life we often base our decisions on the mode of a distribution. For example, in determining how much to contribute to a certain fund, we tend to be guided by the amount

most commonly contributed by others. This is using in our thinking the mode of a distribution.

The use of the mode as a measure can be illustrated by the following contributions of the members of a fraternity to a homecoming fund.

Table 11.—Data to Illustrate the Calculation and Use of the Mode: Numbers Represent Contributions to a Fund

Amount Contributed	*f*	*Total Amount*
$25.00	1	$25.00
10.00	2	20.00
5.00	1	5.00
3.00	2	6.00
2.50	15	37.50
1.00	3	3.00
	24	$96.50

The mode in this case is $2.50, the amount contributed by 15 of the students. This is the most helpful single fact for a student who wants to determine what he shall give. The mean contribution is $4.02; this figure is not representative of the group, since it is unduly influenced by three large gifts. The median amount in this case is identical with the mode. When the scores are grouped the median is often unnecessarily accurate, and for drawing conclusions is not as valuable as the more general modal figure.

Accordingly, it is apparent that for certain purposes the mode has its place in describing a distribution. It can be used advantageously to determine what should be the allowance for a child's spending money, whether a person is up to the general level in any performance, what size of shoe should be kept in stock for most customers, and other facts of a similar nature. The mode has a relatively small place in the work of this course.

Finding the mode of a distribution of scores rarely presents a problem. The mode is always that score which occurs most frequently. If two or more scores occur with equal frequency, we have more than one mode. Thus, the mode of the following scores is 56, since this number occurs most often: 60, 60, 58, 56, 56, 56, 54, 53. If a third score of 60 were included, the record would have two modes, 60 and 56. It would then be a bi-modal distribution.

With scores that are grouped in intervals, the midpoint of the interval having the largest number of scores is taken as the modal score. For example, in Table 5, page 138, most scores fall within the interval between 66 and 68; the mode is at the midpoint of this group, or at 67.

Which of the three measures to use. Each of the three measures discussed in this chapter has its particular use in the description of the general level of a distribution. The effort to represent facts as they are, necessitates the use in a particular situation of a particular measure, and in another situation of a different measure. The average alone gives an adequate description if every score must contribute its part to the final result. This would be the preferred measure in determining the daily income from an occupation such as selling, in which the income varies from day to day. Again, the description of performance records which contain extreme scores requires a knowledge of the median performance. The evidence indicates that the median of several examination grades is a more accurate description of a student than is the mean. Finally, in those fields in which the expected performance is not an absolute amount, but is conformity with the performance of others, we need the mode. We ask for the mode of a group record in determining how much to spend for clothes. The time spent daily in physical exercise is best described by the modal amount—this is the most accurate description, for it will exclude figures for rainy days or a vacation period, neither of which is representative. It is worth noting that we tend to carry that impression of a person which constitutes his modal performance. We class others as steady workers, as spendthrifts, or as rapid readers by the mode of their record, rather than by other descriptions of the central tendency.

Other descriptions of a record: quartiles, percentiles, deciles. The general level of the record of a person or of a group is described by the mean, the median, and the mode. With group performances, however, it is often important to describe the record in such a way that any individual record can be located with reference to other records. Such a description is based on the ranks of the scores. If we want to state in which quarter of the group a particular score lies, the serially arranged scores are divided into four equal parts by locating points at the quartile positions; if we want to locate a score in its particular tenth of the distribution, we locate the deciles; and if we want the rank of the score among 100 scores, we find the percentile positions.

The meanings of the terms correspond to those in general use for similar words. The quartile is one of the points which divide the group into four quarters; the highest quartile (Q_3) is the point above which fall 25% of the scores and below which fall 75%; the middle quartile (Q_2) is identical with the median; the lowest quartile (Q_1) is the point above which fall 75% and below which fall the other 25%. The deciles divide a group of scores arranged in order of magnitude into ten equal groups; the fourth decile is the point in the distribution below which fall 40% of the scores and above which fall the remaining 60%. The percentile in a series of scores is the point below which lies the percentage of the group indicated

by the particular percentile number; to say, for example, that a score is the 93rd percentile means that 7% of the scores are above it and 93% below it.

A description of the group in terms of the positions or the ranks occupied by different scores is useful when one individual is being compared with others in the group. For example, by showing that a person's score falls in the best tenth of a group we demonstrate that his performance is better than that of 90% of the group. The comparison of an individual in several tasks is also rendered possible by finding the ranks of his scores in the groups that performed the tasks. The comparative standing of a person in algebra and history, for example, is revealed quite clearly by the fact that in one subject his record is with the 90th percentile and in the other with the 25th percentile. Even the simple serial ranking of the scores of a group from the largest to the smallest tells us more about any one score than does its absolute value. To know that a person ranked 43rd in a group tells somewhat more than knowing that his score was 62; our knowledge gains in definiteness when we learn that his score was the 43rd in a group of 50, or that its rank was the 4th quartile, or the 9th decile, or the 86th percentile.

The method of finding the different positions of the scores in a group, and assigning a rank to each, will be illustrated with the data of Table 12. The scores are first arranged in the order of size. The best score (the largest when the unit of measure is the amount done, and the smallest when it is the time required or the errors made) is placed at the top, and assigned the highest rank in the group. This is continued in order for all the scores; at the bottom is the poorest score, which has the rank of 1.

This procedure places the scores roughly in order. The true rank of each score now has to be found. No problem arises with reference to the three leading scores; the rank of each is that indicated by the order in which it appears. The score of 94, however, was made by two individuals, and its rank is the average of 23 and 24, or 23.5. The three scores of 92 are given the rank of the average of 19, 20, and 21, or 20; the four scores of 83 are given the rank of the average of 11, 12, 13, and 14, or 12.5; the three scores of 70 receive the rank of the average of 6, 7, and 8, or 7; finally, the first six scores, which are all 65, receive as their rank the average of the first six figures, or 3.5. The true ranks of the scores are given in the third column.

Since the group includes 27 scores, each quarter will have $\frac{1}{4}$ of 27, or $6\frac{3}{4}$ scores; the lowest quartile (Q_1) is at a point $6\frac{3}{4}$ scores from the lowest score. This would normally include in the first quarter the first 7 scores, but since the 7th, 8th, and 9th scores are all 70, the three must be included with the quarter which has the largest proportion of these, the second. The second quartile (Q_2) is the same as the median, and extends through $13\frac{1}{2}$ scores; all the scores of 83 fall into the second quarter.

TABLE 12.—DATA TO ILLUSTRATE THE MEANING AND CALCULATION OF RANKS

Score	*Order*	*Rank*	*Quartile Rank*	*Decile Rank*	*Percentile Rank*
98	27	27	4	10	100.0
96	26	26	4	10	96.3
95	25	25	4	10	92.6
94	24	23.5	4	9	87.0
94	23	23.5	4	9	87.0
93	22	22	4	8	81.5
92	21	20	3	8	74.1
92	20	20	3	8	74.1
92	19	20	3	8	74.1
88	18	18	3	7	66.7
87	17	17	3	7	63.0
86	16	16	3	6	59.3
85	15	15	3	6	55.6
83	14	12.5	2	5	46.3
83	13	12.5	2	5	46.3
83	12	12.5	2	5	46.3
83	11	12.5	2	5	46.3
79	10	10	2	4	37.0
70	9	8	2	3	29.6
70	8	8	2	3	29.6
70	7	8	2	3	29.6
65	6	3.5	1	1.5	13.0
65	5	3.5	1	1.5	13.0
65	4	3.5	1	1.5	13.0
65	3	3.5	1	1.5	13.0
65	2	3.5	1	1.5	13.0
65	1	3.5	1	1.5	13.0

The third quartile (Q_3) is at a point ¾ of 27, or 20¼ scores, from the lower end of the scale. The scores from 85 through 92 have the rank of the third quarter, and those above 92 of the fourth quarter.

The decile points are separated by 1/10 of 27, or 2.7 scores. Accordingly, the first decile is 2.7 scores from the beginning of the series; the second, 5.4; the third, 8.1; the fourth, 10.8; and so on for the entire distribution. In assigning the decile rank, it should be noted that the first six scores must be given the same rank, because they are identical. Since these scores include both the first and second deciles, the decile rank is the average of

the two, or 1.5. The third decile is 8.1 scores from the beginning, and extends slightly beyond the second score of 70. The three scores of 70 must all be given the same decile rank; namely, 3. The fourth decile extends to 10.8; since this includes only one of the scores of 83, all must be given the higher rank. The score of 79 is ranked in the fourth decile. Similarly, other decile ranks in the table can be found.

The same method is used in locating the percentiles and in determining the percentile ranks of the scores. The score of 98 has the 100th percentile rank, since no other scores are above it. The score of 96 is 26/27 of the distance from the bottom; its percentile position is 26/27 of 100, or 96.3. The score of 87 is seventeenth from the bottom; accordingly, its percentile rank is 17/27 of 100, or 62.96. Scores of the same numerical value have the percentile rank of their average position. Thus, the three scores of 83 are, on the average, 12.5 scores from the lowest score; hence their percentile position is 12.5/27 of 100, or 46.3. The other percentile ranks given in the table are found in a similar manner.

The method used when the scores are grouped into class intervals introduces no new principles. Thus, to find the point reached by the ablest 1/10 of the subjects whose scores are given in Table 13, we count off 6.6 scores (1/10 of 66 = 6.6). Counting from the higher scores: $1 + 3 + 3 = 7$. This extends a small amount beyond the required 6.6, and we would obtain a reasonably accurate figure for the ablest 1/10 by saying that their scores reach 121 or 122, which is a little higher than the score of 120 reached by 7 out of the 66 subjects.

Accurate calculation by the method explained for finding the median, gives the exact figure as 121.33. This is the 9th decile, or the 90th percentile score.

To find the eighth decile (the point exceeded by 2/10 of the subjects) we count off 2/10 of 66, or 13.2, from the highest score; thus, $1 + 3 + 3 + 9 = 16$. This extends beyond the required 13.2. Inspection indicates that the score will be closer to 110 than 120; about ⅓ of the scores in this interval are not used, and we place the eighth decile at approximately 113. Exact calculation places the eighth decile at 113.1.

The lowest decile lies 6.6 scores above 40; counting, $1 + 1 + 6 = 8$. The decile point lies closer to 70 than to 60, and an approximation of 67 or 68 is easily made. Exact calculation gives 67.7.

The method described may be used to calculate any percentile. The highest score is given the 100th percentile rank, since it is exceeded by none, and the lowest is given the 0 position, since it is exceeded by all. Any intermediate percentile is found by counting as was done for the deciles. For example, the 35th percentile is found by counting 35% of 66, or 23.1 scores, from the lower end: $1 + 1 + 6 + 8 + 13 = 29$. This extends nearly halfway beyond the required point in the last group of 13 scores;

the approximate score is near 85. Exact calculation places the score at 84.69.

Additional results are given in Table 13.

The quartile points in the distribution will be located in the section on quartile deviation.

TABLE 13.—SCORES IN A SUBSTITUTION TEST, WITH PERCENTILE AND DECILE SCORES

Score	*f*	*Percentile*	*Score*
150—159.9	1	100	159
140—149.9	0	90	121
130—139.9	3	80	113
120—129.9	3	70	106
110—119.9	9	60	100
100—109.9	10	50	93
90— 99.9	10	40	88
80— 89.9	13	30	82
70— 79.9	9	20	76
60— 69.9	6	10	68
50— 59.9	1	0	40
40— 49.9	1		
	66		

A Short Method for Finding the Arithmetic Mean in Grouped Data

In order to avoid the cumbrous procedure of finding the mean by the long method described in this chapter (as a matter of fact, the long method proves the simpler when the number of scores does not exceed 20 and when the scores scatter themselves over a wide range), a shorter method called the *guessed mean method* is often employed. After the scores have been classified into a frequency distribution, the mean is assumed to fall at any convenient point in the distribution; generally, the position of the mode is adopted. A third column is now established, as illustrated in the table on page 158, to parallel column *f*. This column is designated as *d*, and consists of a simple arithmetic series 0, 1, 2, 3, 4, 5, and –1, –2, –3, –4, –5, –6, which indicates the *number of step-interval deviations* above and below the position of the assumed or guessed mean. The deviations below the assumed mean are regarded as negative; those above are regarded as positive. A fourth column designated as *fd* parallels column *d*. The letter *f* stands for frequency; the letter *d* stands for deviation. The expression *fd* means that every *f* value in column 2 is multiplied by its corresponding or parallel *d* value in column 3. Column *f* is added to give the total number of scores. Column *fd* is next added, and this addition is algebraic: the plus and minus signs are taken into account. The plus values and the minus values are added separately, and the proper sign is affixed to each. Now the smaller is subtracted from the larger,

and the result is given the sign of the larger. The values are substituted in the formula given with the tabulation.

The assumed mean is the midpoint of the step interval 110–114, or 112.5.

Scores	*f*	*d*	*fd*
135–139	1	5	5
130–134	3	4	4
125–129	3	3	9
120–124	2	2	4
115–119	6	1	6
110–114	13	0	0
105–109	9	–1	–9
100–104	4	–2	–8
95– 99	7	–3	–21
90– 94	2	–4	–8
85– 89	3	–5	–15
80– 84	2	–6	–12
N =	55		28
			–73
		Sum of *fd* =	–45

$$\text{True mean} = \text{Assumed mean} + \frac{\text{Algebraic sum of } fd}{\text{No. of scores}} \times I$$

In the formula, I represents the size of the step-interval, in this instance 5. Hence:

$$\text{Mean} = 112.5 + (-45/55 \times 5) = 108.4.$$

Exercises in Calculating the Central Tendency, Deciles, and Percentiles

The data from the experiments are preferable for use in the calculations on this topic. In case these are not available, the exercises below will serve to acquaint the student with the use of the methods discussed in the present chapter. For many purposes sufficient facility has been acquired if a new problem can be readily worked with free use of the note book and the manual. The mean, the median, and the mode are to be found for the data given in each exercise. Decile and percentile points are to be found as assigned by the instructor.

1. The number of drill problems required by different members of a class before each was able to calculate the exact median in exercise 8, below: 12, 9, 9, 8, 6, 6, 5, 5, 5, 5, 5, 5, 5, 5, 5, 4, 4, 4, 4, 4, 3, 3, 3, 2, 2, 2, 1, 1, 0, 0.

2. The number of drill problems required by different members of a class before each was able to calculate, by the short method, the mean in exercise 8, below: 7, 6, 6, 5, 5, 4, 4, 4, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 2, 2, 2, 2, 2, 2, 2, 1, 1, 1.

3. The ages of the presidents at the time they were inaugurated: 57, 62, 58, 58, 59, 62, 55, 68, 51, 50, 65, 60, 49, 60, 52, 57, 47, 54, 49, 51, 48, 55, 56, 54, 43, 52, 56, 51, 51, 50.

4. The daily standings in spelling, for a month, of a girl in the seventh grade: 86, 88, 86, 84, 90, 99, 82, 80, 86, 92, 84, 82, 82, 80, 86, 94, 84, 94, 88, 90.

5. The mean for the month of each pupil in the same seventh-grade class: 98, 96, 95, 93, 91, 90, 89, 89, 88, 88, 88, 88, 87, 87, 85, 85, 84, 84, 84, 83, 91, 80, 80, 79, 79, 77, 76, 74, 70.

6. Average time in minutes required by a group for working five problems in an arithmetic test: 18, 19, 20, 20, 22, 24, 25, 28, 28, 30, 33, 35, 38, 40, 40, 42. The figures represent the time for successive trials.

7. The record of a second group on the same arithmetic test: 14, 15, 16, 16, 17, 18, 18, 20, 20, 22, 24, 25, 29, 30, 30, 32, 33, 34, 40.

8.

Score	*f*
42—44.9	1
39—41.9	2
36—38.9	3
33—35.9	5
30—32.9	6
27—29.9	7
24—26.9	7
21—23.9	4
18—20.9	1
15—17.9	2

9.

Score	*f*
35—39.99	1
40—	0
45—	3
50—	4
55—	7
60—	6
65—	9
70—	8
75—	5
80—	3

10.

Score	*f*
40—41.9	2
38—	1
36—	3
34—	3
32—	6
30—	4
28—	4
26—	4
24—	1
22—	1

CHAPTER 17

Describing a Variable Record: The Variability

By the variability of a record is meant the scattering or the spread of the scores about the central tendency. It was pointed out in chapter 14 that two performance records may have the same average but still be quite different. This difference will lie in the fact that one performance is more consistent, more homogeneous, or less variable than the other. The need for accurately describing this variability has led to the development of several measures for expressing it; each of these measures is valuable for a special purpose. This chapter will introduce the following measures of variability: (1) the range; (2) the quartile deviation; (3) the average deviation; (4) the standard deviation.

The range. The range is the difference between the largest and the smallest scores. It takes into account merely the two extreme scores and is, therefore, only a crude description of the variability. Its inadequacy for precise calculations can be seen in the fact that two records with equal ranges are not equally variable. The following standings of two students illustrate the point.

Student A: 40, 89, 88, 89, 90
Student B: 40, 75, 60, 90, 50

The range of each of the two records is 50 (90 — 40), but it is apparent that student A is, with the exception of the first record, very uniform in his performance; student B has an inconsistent record throughout. The range does not state the facts completely, and it has a very limited use in scientific work.

The quartile deviation (Q). To eliminate the effect of the two extreme scores on the measure of variability, experimenters employ the quartile deviation (Q) as a measure of variability. The quartile is defined as one-half of the range over which the middle 50% of the scores spread. In a normal distribution it would be the range from the median or mean score to a score at the 25th or the 75th percentile point. The measure is not affected by one or two extreme scores, since only the middle 50% of the scores determine its size.

To find the quartile deviation, it is first necessary to calculate the lower quartile point (Q_1) below which are ¼ of the scores, and the upper quartile point (Q_3) above which are ¼ of the scores. These quartile points are found in exactly the same way as is the median. The procedure will be illustrated with the data of Table 13, page 157. The point below which ¼ of the scores lie is ¼ of 66, or 16½ scores, from the lower end. Counting, $1 + 1 + 6 = 8$; 8½ scores ($16\frac{1}{2} - 8 = 8\frac{1}{2}$) from the group of 9 are needed to reach Q_1. It is assumed that the 9 scores are distributed evenly over the range from 70 to 80. The 8½ scores will extend $\frac{8\frac{1}{2}}{9}$ of this distance. Therefore, $\frac{8\frac{1}{2}}{9}$ of 10, or 9.4, is the distance above 70 to the lower quartile. $70 + 9.4 = 79.4$, the lower quartile, or Q_1.

To find Q_3, the same process is followed with the upper end of the distribution. Counting, $1 + 0 + 3 + 3 + 9 = 16$; hence, to reach the third quartile requires ½ score ($16\frac{1}{2} - 16$) from the group of 10 scores that lie between 100 and 110. Therefore:

$$\frac{\frac{1}{2}}{10} \text{ of } 10 = \frac{5}{10}, \text{ or } .5, \text{ the distance below 110 to } Q_3$$

$$110 - .5 = 109.5, \text{ the upper quartile, or } Q_3.$$

We can now state in figures the extent of dispersion or scatter of the scores in Table 13. The quartile deviation, abbreviation Q, is ½ of the distance between the first and third quartiles. Expressed as a formula, this becomes:

$$Q = \frac{Q_3 - Q_1}{2}.$$

Substituting the values found:

$$= \frac{109.5 - 79.4}{2} = \frac{30.1}{2} = 15.05.$$

The quartile of 15.05 is about ⅛ of the range of 120. This indicates a wide distribution of the scores, since Q is generally less than 1/10 of the range.

The average deviation (AD) or mean deviation (MD). The methods of describing variability discussed in the preceding paragraphs have taken into account only the distance of two scores from each other. For the range, the two scores are the largest and the smallest; for the quartile deviation, the two scores lie at points which are 25% of the scores from each of the ends.

A measure which is more accurate for many purposes is one that takes into account *every* score instead of only two. This is done by the *average deviation* (*AD*), which means, as the term indicates, the average of the de-

viations of every score from the central tendency. (In most cases the mean is used as the central tendency; the median is used in certain problems, but the mode is rarely used.)

The meaning of the term and the method of calculating it will be illustrated by means of a problem. Suppose a pupil has the following record for 9 days, for working original exercises in geometry: 8, 5, 3, 9, 9, 6, 10, 7, 6. The *average* number worked is 7. The first day the pupil deviated 1 from this average; the second 2; the third 4; the fourth 2; the fifth 2; the sixth 1; the seventh 3; the eighth 0; the ninth 1. Adding these separate deviations, $1 + 2 + 4 + 2 + 2 + 1 + 3 + 0 + 1$, gives 16. Since this was for 9 days, the *average* deviation is $16 \div 9$, or 1.78.

The two records given in Table 14 illustrate further the meaning of the average deviation and the method of computing it.

The deviations are taken from the median. For subject *A* these deviations amount to 20. Therefore, the average deviation is $20 \div 9$, or $2\frac{2}{9}$. For subject *B*, the total of the deviations is 12, and the average deviation is $12 \div 9$, or $1\frac{1}{3}$. The results show that subject *B* is much more consistent in her performance than is subject *A*.

With grouped data, the calculation of the average deviation follows the same procedure as that described in preceding paragraphs. The midpoint of each group is taken to represent the value of each score in the group. This is illustrated in the calculation of the standard deviation, page 163. It is more important at this time to see how variability can be definitely measured than to gain facility in calculating particular measures.

The standard deviation (SD), or sigma (σ). The calculation of the average deviation does not conform rigidly to mathematical principles. It will be apparent from Table 14 that if the deviations larger than the median are positive, those smaller than the median are negative. This fact was, however, not taken into account. To make use of the signs would tend toward a zero sum when the positive and negative deviations are added, and the average deviation would lose its meaning.

A process definitely in accord with mathematical principles can, however, be employed with the same general approach to the problem. If each of the deviations is squared, all will be positive. From the sum of the squares the square root must be taken. The process here roughly indicated will give the standard deviation. It is the most accurate of all measures of variability, and the one most frequently used in careful studies. It is abbreviated as *SD*, or more commonly by the Greek letter sigma, σ. The formula reads as follows:

$$SD = \sqrt{\frac{\Sigma d^2}{N}}.$$

The sum of the differences squared (designated in the formula by Σd^2)

TABLE 14.—DATA TO ILLUSTRATE THE COMPUTATION OF THE AVERAGE DEVIATION, AND TO COMPARE TWO RECORDS IN VARIABILITY: SCORES IN A MEMORY TEST CONSISTING OF TWENTY-FIVE WORDS

Subject A Words Recalled	*Subject A* Deviations From Median	*Subject B* Words Recalled	*Subject B* Deviations From Median
22	5	20	3
22	5	19	2
18	1	18	1
18	1	18	1
17 Median	0	17 Median	0
17	0	17	0
16	1	16	1
14	3	15	2
13	4	15	2
	20		12

is divided by N to find the average for the group, and of this average the square root is taken. The standard deviation is always calculated from the average of the distribution, never from the median or the mode.

The calculation is illustrated by the data of Table 15. The average of the scores is 32, and the deviation of each score from 32 is given in the column headed d. The sum of the squares of the deviations is 888. Therefore:

$$SD = \sqrt{\frac{888}{12}} = \sqrt{74} = 8.6.$$

TABLE 15.—DATA TO ILLUSTRATE THE CALCULATION OF THE STANDARD DEVIATION

Scores	d	d^2
45	13	169
44	12	144
42	10	100
40	8	64
35	3	9
32 = average	0	0
29	–3	9
26	–6	36
25	–7	49
24	–8	64
22	–10	100
20	–12	144
		Sum of d^2 = 888

The process is the same for a grouped distribution; the deviations of the midpoints are found, and these are squared. The process is shown, in the section devoted to the solution of problems, on pages 165-167, together with a short method by which the tedious number work may be avoided.

Relation of AD, SD, and Q to each other and to normal curve. If Q is laid off in both directions from the mean in a normal distribution, it will extend to Q_3 and Q_1; this range includes exactly 50% of the scores. If AD is similarly laid off, it will include 57.5% of the total scores. If SD is laid off in this manner, it will include 68.26% of all the scores. Accordingly, it is apparent that SD is the largest of the three measures and Q the smallest; it is often possible to check against errors by noting whether AD is smaller than SD.

It should also be noted that three times the standard deviation in a normal distribution includes over 99% of the total scores.

Comparison of the variability of records having different central tendencies: the coefficient of variability. In the discussion of the average deviation the variability of two records was compared by finding the average deviation of each. Such a comparison has meaning only when the average or the median of the records to be compared is the same, or nearly so. Suppose the record of a child is compared with the record of subject *A*, given in Table 14, page 163. The child's record of recalled words is 4, 3, 5, 5, 1, 4, 9, 9, 0. The median is 4, and the deviations are 0, 1, 1, 1, 3, 0, 5, 5, 4, or a total of 20. The average deviation is $20 \div 9$, or $2\frac{2}{9}$, a deviation identical with that found for the record of subject *A*. General inspection will show, however, that the child's performance is much more variable than that of subject *A*. It has two scores larger than twice the average, and one score is zero.

In problems of this kind, the average deviation becomes significant only if it is seen in relation to the size of the median. The smaller the median the greater the variability indicated by a given average deviation. This fact is expressed numerically by dividing the average deviation by the median. In the problem discussed, this gives for subject *A*, $2\frac{2}{9} \div 17$, or .13, and for the child, $2\frac{2}{9} \div 4$, or .56. The two figures, .13 and .56, show the relative variability of the two records.

In practical work the two figures, .13 and .56, are multiplied by 100 to dispose of decimals. The answer is now known as the *coefficient of variability* (or *variation*). It is expressed by the formula:

$$V = \frac{100 \times AD}{M \text{ or } Med}, \text{ or } V = \frac{100 \times SD}{M}$$

The denominator may be the median or the mean, depending upon which was used in finding the deviations. In place of the average deviation, the standard deviation may be used. The coefficient of variability for the child in the activity here cited is 56, and for subject A, 13.

The importance of the coefficient of variability is seen in problems such as the following. Suppose the weights of 5 horses are compared in variability with those of 5 dogs.

Weights of Horses	*d*	*Weights of Dogs*	*d*
1520	20	80	20
1510	10	70	10
1500	0	60	0
1490	10	50	10
1480	20	40	20
	—		—
	60		60

The average deviation in each case is 60 ÷ 5, or 12. It would be impossible for most people to arrange the five horses in the order of their weight, but the dogs are easily recognized as different. This shows the insufficiency of the average deviation for the purpose intended. The coefficient of variability makes possible a comparison of variability, as is seen from the calculation below.

$$\text{For the horses:} \quad V = \frac{100 \times 12}{1500} = .8$$

$$\text{For the dogs:} \quad V = \frac{100 \times 12}{60} = 20.$$

These results show that the dogs are much more variable than the horses.

A Short Method for Calculating the Standard Deviation

The standard deviation will be calculated first by the direct application of the formula discussed in this chapter. Following that, the same problem will be worked by a shorter method.

Scores	*f*	*Midpoint*	*d*	d^2	fd^2
175—199.9	4	187.5	79.7	6352.09	25,408.36
150—174.9	10	162.5	54.7	2992.09	29,920.90
125—149.9	13	137.5	29.7	882.09	11,467.17
100—124.9	15	112.5	4.7	22.09	331.35
75— 99.9	10	87.5	20.3	412.09	4,120.90
50— 74.9	8	62.5	45.3	2052.09	16,416.72
25— 49.9	8	37.5	70.3	4942.09	39,536.72
0— 24.9	2	12.5	95.3	9082.09	18,164.18
	70				145,366.30

The average used in the calculation is 107.8; this can be found by the short method described in the last chapter. Substituting the data from the problem in the formula gives the following results:

$$SD = \sqrt{\frac{\Sigma fd^2}{N}} = \sqrt{\frac{145{,}366.30}{70}} = \sqrt{2{,}076.66} = 45.5.$$

The same exercise may be worked by the short method if the proper values are substituted in the following formula (I stands for the size of the interval):

$$SD = \left[\sqrt{\frac{\Sigma fd^2}{N} - \left(\frac{fd}{N}\right)^2}\,\right] \times I.$$

Expressed in terms of intervals, the exercise will be in the following form:

Scores	*Interval*	*f*	*fd*	d^2	fd^2
175—199.9	7	4	28	49	196
150—174.9	6	10	60	36	360
125—149.9	5	13	65	25	325
100—124.9	4	15	60	16	240
75— 99.9	3	10	30	9	90
50— 74.9	2	8	16	4	32
25— 49.9	1	8	8	1	8
0— 24.9	0	2	0	0	0
		70	267		1,251

Substituting in the formula gives the following for an interval of 1:

$$\begin{aligned} SD &= \sqrt{\frac{1251}{70} - \left(\frac{267}{70}\right)^2} \\ &= \sqrt{17.87 - 3.814^2} \\ &= \sqrt{17.87 - 14.55} \\ &= \sqrt{3.32} \\ &= 1.82. \end{aligned}$$

Accordingly, 1.82 is the *SD* for an interval of 1. Then:

$$1.82 \times 25 = 45.5, \text{ the } SD \text{ for an interval of } 25.$$

The calculation throughout is performed on an exercise that has an interval of 1 instead of 25, and the deviations are taken from 0, an assumed or guessed figure, instead of the true mean. Due to the fact that the deviations are taken from substituted figures, a correction is necessary. This is the average of the sum of the fd column squared, which must be subtracted from the fd^2 column.

Exercises in Calculating the Variability of a Distribution

1. In which subject is the following class more variable? The standings in history are: 94, 93, 90, 89, 97, 86, 85, 84, 84, 84, 83, 80, 80. In spelling the standings are: 86, 85, 85, 83, 83, 83, 82, 82, 82, 80, 80, 80, 78, 75. Base on *AD* and coefficient of variability.

2. The following are the weights of a group of men and of a group of children. Which group is more uniform? Base on *AD* and *V*.

Children:	46, 52, 54, 57, 59, 60, 60, 63, 64, 65, 72, 78.
Men:	153, 160, 160, 163, 168, 170, 174, 178, 178, 179, 187.

3. Find the quartile for the following scores: 40, 40, 38, 37, 36, 36, 36, 35, 35, 35, 35, 35, 34, 34, 34, 33, 33, 32, 31, 30, 28.

4. Find the variability in the heights of the following men from a university training camp. Base on *SD*.

Height	*f*	*Height*	*f*
75	1	67	108
74	5	66	90
73	8	65	54
72	25	64	38
71	80	63	12
70	88	62	11
69	114	61	3
68	132		
			769

CHAPTER 18

The Relationship Among Measures: Correlation

The problem. In preceding chapters we dealt with the problem of describing the performance of individuals and of groups. So far as many investigations are concerned, the description of facts is completed with these measurements. However, other questions arise. After measuring the attainment in both composition and algebra—to illustrate the further questions—we may inquire whether the subjects who are best in composition are also best in algebra, and whether those who are poorest in one are also poorest in the other. In everyday life the answers to such questions are based on rough inspection; we shall undertake to determine the answers exactly. *How closely are certain measures, certain capacities, and certain kinds of responses related?* Does large ability in one field mean large ability in another, or is strength in one balanced by weakness in the other? If information is accessible on one set of facts, say height, can we tell anything about another set, say weight?

Many capacities or events are not related at all; the height of an adult indicates nothing about his musical ability, or about the number of letters in his name. Other capacities or events are very closely related; the number of yards of cloth bought at a given price, and the amount paid, show perfect correlation. The height of a person is rather closely related to his weight, and less closely to his strength. Again, many events are related inversely: a high rank in one means a low rank in the other. The standings of pupils are inversely related to the number of days that they were absent from classes—those who have the largest number of absences will have the lowest standing. The amount of ice that forms in a region varies inversely with the heat that the area receives from the sun.

Degrees of relationship. The different degrees of relationship are expressed by numbers that range from +1 to —1. Perfect relationship, such as that which exists between the different sums spent for sugar and the number of pounds received, is expressed by +1. Perfect inverse relationship, such as that between the amount in the savings account and the amount in the spending account—the total remaining the same—is expressed by —1. Between these extremes all shades of relationship may exist. For example, a relationship of .85 is somewhat less than the perfect relationship described above. The rate of walking for children below 12 years of age correlates probably .70 with age; that of men above 70, probably —.50.

The measure of the degree of relationship between variable activities is known as the *coefficient of correlation,* and is designated by a number of symbols, each representing the result from a particular formula; two formulas, with their symbols r and ρ (rho), will be presented below. The concept of correlation was developed principally by Karl Pearson, of the University of London, following the suggestion of Galton; it came into use about 1895. The discovery of a method for measuring relationships is one of the great contributions that this age has made to scientific thinking, and it should be understood by all students in the field of human behavior.

Calculating the coefficient of correlation. The methods by which the different formulas for finding the coefficient of correlation were derived are outside the province of this course. Students interested in mathematics can, however, readily follow the process by referring to special books in the field. Two formulas will be applied to problems, and it will be shown that they give the expected results.

Rank-difference method (Spearman method) for measuring correlation. The simpler formula for determining relationship is that based on ranks, rather than on the numerical scores of the individuals in the two tests. The method to be presented is one of two credited to Charles Spearman of England, and the result is at times called the Spearman coefficient. The coefficient is designated by the Greek letter ρ (rho), and is derived by the formula:

$$\rho = 1 - \frac{6 \Sigma d^2}{N (N^2 - 1)}.$$

The symbol d represents the differences between the ranks occupied by the subjects in the two capacities between which the relationship is being determined; the differences in the ranks determine the degree of relationship, and this fact has given the method its name, that of *rank-differences.*

The application of the formula is illustrated in the following brief problems.

TABLE 16.—DATA TO ILLUSTRATE THE CALCULATION OF THE COEFFICIENT OF CORRELATION: MODERATE AGREEMENT

Subject	*Rank in Arithmetic*	*Rank in History*	d	d^2
A	1	2	1	1
B	2	1	1	1
C	3	5	2	4
D	4	4	0	0
E	5	3	2	4
			Sum of d^2 =	10

Substituting in the formula gives the following results:

$$\rho = 1 - \frac{6 \times 10}{5\ (25 - 1)} = 1 - \frac{60}{120} = 1 - \frac{1}{2} = \frac{1}{2} = .50.$$

Hence, the coefficient of correlation is .50. This represents a moderate agreement, and puts in definite numerical form what one would expect from general inspection of the figures.

TABLE 17.—DATA TO ILLUSTRATE THE CALCULATION OF THE COEFFICIENT OF CORRELATION: PERFECT AGREEMENT

Pupil	*Rank in Arithmetic*	*Rank in History*	*d*	d^2
A	1	1	0	0
B	2	2	0	0
C	3	3	0	0
D	4	4	0	0
E	5	5	0	0
F	6	6	0	0

Substituting in the formula gives:

$$\rho = 1 - \frac{6 \times 0}{6 \times (36 - 1)} = 1 - \frac{0}{210} = 1 - 0 = 1.$$

The agreement in this case is perfect, as can be seen from examination of the ranks in the table.

TABLE 18.—DATA TO ILLUSTRATE THE CALCULATION OF THE COEFFICIENT OF CORRELATION: INVERSE RELATIONSHIP

Pupil	*Rank in Arithmetic*	*Rank in History*	*d*	d^2
A	1	7	6	36
B	2	6	4	16
C	3	5	2	4
D	4	4	0	0
E	5	3	2	4
F	6	2	4	16
G	7	1	6	36
				112

Substituting the results in the formula gives:

$$\rho = 1 - \frac{6 \times 112}{7 \times (49 - 1)} = 1 - 2 = -1.$$

The result shows perfect inverse correlation, as can be seen from examination of the data in the table.

Products-moments method: the Pearson coefficient. The Pearson formula, often called the products-moments formula, is employed when the scores of subjects, instead of the ranks, are given. It is much more accurate than the method based on ranks, since ranks do not take into account the *amount* of the difference between two subjects. The Pearson formula is the one most commonly used for accurate measurements of relationship.

Many variations of the formula, developed largely in an effort to abbreviate the calculations, are in existence. In one of the forms most commonly used the formula reads as follows:

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \cdot \Sigma y^2}}.$$

The two symbols x and y stand, respectively, for differences from the average in the first and the second test. The method is readily understood, but the calculation is often protracted. A problem based on the data of Table 19 is worked below.

When the average contains fractional amounts, the calculation is complicated. In practice work, a fraction to the nearest half may be employed, since the main object is familiarity with the use of the formula. Calculating machines, or tables giving the products and the square roots of numbers, facilitate the work. The entire process can be done with machines; the interpretation of the result, rather than the method of finding the result, needs to be emphasized.

Table 19.—Data to Illustrate the Calculation of the Coefficient of Correlation by the Products-Moments Method, or the Pearson Formula

Subject	*Test 1, Score*	*Test 2, Score*	x	y	x^2	y^2	xy
A	60	21	17	1	289	1	17
B	51	25	8	5	64	25	40
C	52	20	9	0	81	0	0
D	39	24	–4	4	16	16	–16
E	50	26	7	6	49	36	42
F	42	18	–1	–2	1	4	2
G	49	19	6	–1	36	1	–6
H	34	20	–9	0	81	0	0
I	24	12	–19	–8	361	64	152
J	32	18	–11	–2	121	4	22
K	40	17	–3	–3	9	9	9
					1108	160	262

Substituting in the formula gives the following:

$$r = \frac{262}{\sqrt{1108} \times \sqrt{160}} = \frac{262}{\sqrt{177{,}280}} = \frac{262}{421} = .62.$$

The Ayres formula for calculating the Pearson coefficient is often employed to abbreviate the numerical work. The formula reads as follows:

$$r = \frac{\Sigma(A \times B) - \begin{matrix}\text{Sum of } A \times \text{Av. of } B \\ \text{or} \\ \text{Sum of } B \times \text{Av. of } A\end{matrix}}{\sqrt{A^2 - (A \times \text{Av. of } A)} \times \sqrt{B^2 - (B \times \text{Av. of } B)}}.$$

A represents the scores in one test, and B the scores in the other test. The same problem that was worked out by the long method is used to illustrate the application of the above formula.

A	B	A^2	B^2	$A \times B$
60	21	3,600	441	1,260
51	25	2,601	625	1,275
52	20	2,704	400	1,040
39	24	1,521	576	936
50	26	2,500	676	1,300
42	18	1,764	324	756
49	19	2,401	361	931
34	20	1,156	400	680
24	12	576	144	288
32	18	1,024	324	576
40	17	1,600	289	680
473	220	21,447	4,560	9,722

$473 \div 11 = 43$, average of A
$220 \div 11 = 20$, average of B

$$r = \frac{9722 - 9460}{\sqrt{21,447 - 20,339} \times \sqrt{4560 - 4400}} = \frac{262}{\sqrt{1108 \times 160}}$$

$$= \frac{262}{\sqrt{177,280}} = \frac{262}{421} = .62.$$

The coefficient of correlation may be found by a method which combines graphical representation with calculation; a correlation chart with special rulings provides for the record of each individual in the two performances, and the calculation is made from this chart.

Results of correlation studies. The coefficient of correlation will gain in meaning as problems employing it are solved. The following are examples of coefficients, all given in round numbers, between various measures: height and weight in same sex and age, .50; height and weight in men of different ages, .45; spelling and drawing, .25; intelligence and certain wood work, —.25; grades and intelligence, .60; tapping with pencil and tapping on instrument, .50; intelligence and grades in trade courses, —.30; mathematics and physics, .75; languages and art, .20; intelligence and size of head, .15.

Coefficients under .35 are used in scientific work, provided they are found consistently in different studies; a number of brief intelligence tests correlate about .60 with college grades, and these are of some help in planning work. It is easier to predict what a group will do than to predict the performance of any individual in the group. Much valuable predicting is done on the basis of tests that correlate over .70.

The extension of the correlation concept. The method of computing relationship here described is extended to include larger problems in psychology. For example, it is possible, by the use of partial correlations, to rule out any factors that affect a given response, and to determine the relationship between any two factors that remain. Thus, both exercise and diet will affect an individual's efficiency. By means of partial correlations it is possible to calculate the effect of exercise alone, the diet being kept constant for all individuals. This use of the correlation concept promises the discovery of causal connections that will illuminate many problems now not comprehended. We do not know which of the many factors that reflect on conduct are really influential, and we may be directing our energies to barren tasks. This topic belongs to later work in the field.

Problems in Correlations

1. The ranks of 22 college women in sensory discrimination (the averages of several tests) and in academic grades, are given below. The ranks in sensory discrimination are given in the first series of figures; the grades are represented by the figures below those for discrimination. To what extent are the two related?

1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16,	17,	18,	19,	20,	21,	22
14,	20,	7,	8,	4,	11,	2,	22,	19,	18,	21,	15,	3,	9,	1,	12,	6,	13,	5,	10,	17,	16

2. A person took a daily record in writing *a*'s for 30 seconds, and in adding columns of equal length for 3 minutes. The records for each day are given below, one above the other. How closely is the ability to write *a*'s related to adding ability?

Writing *a*'s	50,	64,	55,	54,	59,	60,	61,	64,	68,	60,	57,	59,	53,	62,	67,	70,	68
Adding	17,	29,	21,	23,	23,	24,	24,	25,	29,	28,	25,	26,	20,	28,	29,	30,	32

3. Below is given the average time in minutes required by groups of children of different ages to learn a poem of two stanzas. How closely is ability to memorize related to age?

Age	6,	7,	8,	9,	10,	11,	12,	13,	14,	15,	16,	17,	18
Time	14,	12,	11,	11,	10,	10,	8,	9,	8,	8,	9,	9,	9

CHAPTER 19

The Reliability of Measures

The problem. We have assumed that a number of measurements must be made in order to establish a person's performance record. However, the number required needs to be determined more definitely. Are 30 sufficient, or will 100 be required? The question introduces us to the problem of the reliability of the mean, the median, the standard deviation, the coefficient of correlation, and every other measure of the individual.

Science answers the question on the reliability of a measure by determining *between what limits the scores from further trials will fall.* The reliability is generally computed in terms of the *probable error* (*PE*), which means the range above and below a given measure in which half of the scores from additional trials will fall. Thus, a score of 80 in letter writing, with a probable error of 10, means that in further trials the chances are even that half of the scores will fall between 80 + 10, or 90, and 80 − 10, or 70; there is an even chance that half of the scores from further trials will fall within this range of 70-90. The probable error of a measure is that range above and below the measure in which, on the basis of chance, fifty per cent of the additional scores will fall.

It would seem that actual trials would be required to determine where additional scores will fall. It is possible, however, to predict what future scores will be by using the scores already found. This will be shown for the average.

The reliability of the average. The formula for the probable error of the average is easily understood, and its explanation will clarify the question of measuring reliability. Two facts about the series of measurements to be tested for reliability should be noted. First, the more scores obtained from an individual, or the larger the group studied—that is, *the larger that* N *is*—the smaller will be the change resulting from additional measurements. Second, *the larger the variability,* the less reliable will a score be. For example, the average of 100 scores is not as apt to be changed by further testing as is the average of 5 scores; also, if 100 scores of an individual lie between 25 and 30, there will not be as much change from 5 additional

scores as if the scores were scattered between 25 and 75. The formula for measuring the reliability can now be made clear:

$$PE_{(M)} = \frac{.6745\ SD}{\sqrt{N}}.$$

The application of the formula in a problem will show its meaning. For example, we have taken 30 measures of some function such as tapping; the mean is 95, and the *SD* is 21. How reliable is this average?

Substituting in the formula, we find:

$$PE_{(M)} = \frac{.6745 \times 21}{\sqrt{30}} = \frac{14.16}{5.5} = 2.6.$$

The result, 2.6, is known as the probable error of the mean of 95. It indicates that with further testing one-half of the future scores will fall between 95 + 2.6, or 97.6, and 95 — 2.6, or 92.4, and that the other half will fall outside this range. To represent the mean with its reliability, the mean is written 95 ± 2.6.

The foregoing problem illustrates how the reliability of the mean of an individual's record is tested. The same process will show whether enough subjects have been tested to give a reliable group average or mean. Suppose the mean weight of 100 students is 112 pounds, and the *SD* is 20. How reliable is this mean? How much would it be changed if an additional group of 100 students were weighed?

Substituting in the formula, we find the following:

$$PE_{(M)} = \frac{.6745 \times 20}{\sqrt{100}} = 1.3.$$

The result shows that the chances are equal that the mean of 112 pounds differs from the true mean by not more than 1.3 pounds. If additional groups of 100 are weighed, half of these groups will have their mean weight between 112 + 1.3 and 112 — 1.3, or between 113.3 and 110.7; the other half of the groups will have a mean outside of this range.

The chances are even that the true mean will fall between 1 *PE* and —1 *PE*. To be practically certain of the limits which will contain the true mean, we measure off 4 *PE* on either side of the mean. These limits will take into account 99.3 of the total distribution. For the problem in question, we are practically certain that the true average from weighing additional groups of students will lie between 112 + (4 × 1.3), or 117.2, and 112 — (4 × 1.3), or 106.8. We have established the mean between the limits of 106.8 and 117.2.

The reliability of other measures. The formulas for several other measures are shown below:

$$PE_{(\text{Med.})} = \frac{.8454\ SD}{\sqrt{N}};$$

$$PE_{(SD)} = \frac{.6745\ SD}{\sqrt{2N}};$$

$$PE_{(r)} = \frac{.6745\ (1 - r^2)}{\sqrt{N}}.$$

The fact should be emphasized that the probable error gives the degree of reliability only if the scores of the individual are genuine measures of his capacity, or if a fair sample of the individuals in a group has been taken. Nothing can be done to correct data which were incorrectly derived, or to determine how much they are in error.

An important application of the measurement of reliability is that of determining whether the difference found between two groups is a genuine difference, or whether additional testing of either or both groups might so change the results that the difference originally found would become insignificant. The reliability of the difference between two groups is tested by the following formula:

$$PE_{\text{(diff.)}} = \sqrt{PE^2_{\text{(av. of 1)}} + PE^2_{\text{(av. of 2)}}}.$$

To be reliable, any difference must be four times as large as the probable error of the difference found by the formula. In the formula, the standard error of the average or mean may be substituted for the probable error of the average. The result is then known as the standard error of the difference, sigma $_{\text{(diff.)}}$. To be reliable, a difference must be at least three times its standard error. Before two groups are compared in any measurement, the reliability of the difference should first be found.

The following problem will illustrate how the difference between two groups is examined for reliability in terms of the standard error of the difference. The students in the liberal arts courses and those in the professional courses in a university were measured for height; the two groups are described in the following figures:

	Liberal Arts	*Professional*
Height	68.6	69.7
SD	2.8	3.7
Number	740.0	1901.0
Sigma $_{\text{(av.)}}$	.103	.085

The standard error of the average, sigma $_{(av.)}$, is found by substituting in the formula:

$$\text{Sigma}_{(av.)} = \frac{SD}{\sqrt{N}}.$$

The values .103 and .085 are found by substituting in this formula.

The standard error of the difference is found by substituting in the formula:

$$\text{Sigma}_{(diff.)} = \sqrt{(\text{Sigma}_{(av.\ of\ 1)})^2 + (\text{Sigma}_{(av.\ of\ 2)})^2}\ .$$

The following results are found by substituting in the formula:

$$\text{Sigma}_{(diff.)} = \sqrt{(.103)^2 + (.085)^2} = .133.$$

The difference in height between the two groups is 69.7 — 68.6, or 1.1. This difference is more than eight times the standard error of .133, and hence is reliable. We could determine in the same manner whether the difference in variability for the two groups would remain unchanged if additional students in each group were measured; the students in professional courses appear to be more variable, but the reliability of the difference would have to be tested before this statement could be safely made.

Problems in Probable Error

1. A spelling test was given to 625 sixth-grade pupils. The results gave a mean standing of 73 per cent and a standard deviation of 8. Assuming that the sampling was carefully made, to what extent might this mean be changed with further testing?

2. In a class of 200 children, the coefficient of correlation between arithmetic and spelling was .43. Assuming that the 200 children were a fair sample, to what extent might further testing modify this figure?

3. The tests mentioned in problem 2 are to be given to similar groups in other cities. Between what limits will half of the coefficients of correlation be found?

4. In a tapping test given to 450 children, the standard deviation is 20. How reliable is this?

5. The mean of 100 trials in tapping is 90, and the standard deviation is 12. How much would the mean and the standard deviation be changed with further testing?

Books on Statistics

For some students, the elementary discussion of statistical problems in the preceding chapters should be supplemented with treatises devoted to statistics. The following books will be found helpful:

Garrett, Henry E., *Statistics in psychology and education.* New York: Longmans, Green & Co., 1926.
Hull, Clark L., *Aptitude testing.* Yonkers-on-Hudson: World Book Company, 1928.
Rugg, Harold O., *Statistical methods applied to education.* Boston: Houghton Mifflin Company, 1917.
Thurstone, L. L., *The fundamentals of statistics.* New York: Macmillan Co., 1927.

APPENDIXES

APPENDIX A.—ILLUSTRATION OF HOW A RECORD IS TO BE DESCRIBED

Record of a Subject in Experiment 7, Rate of Writing Letters

al	*Score*	*d*	*d*²
.	78	2.7	7.3
.	81	5.7	32.5
.	75	− .3	.1
.	78	2.7	7.3
.	78	2.7	7.3
.	78	2.7	7.3
.	75	− .3	.1
.	83	7.7	59.3
.	73	−2.3	5.3
.	85	9.7	94.1
.	82	6.7	44.9
.	75	− .3	.1
.	70	−5.3	28.1
.	77	1.7	2.9
.	77	1.7	2.9
.	76	.7	.5
.	76	.7	.5
.	74	−1.3	1.7
.	69	−6.3	39.7*
.	77	1.7	2.9
	73	−2.3	5.3
	74	−1.3	1.7
	72	−3.3	10.9
	77	1.7	2.9
	78	2.7	7.3
	70	−5.3	28.1
	75	− .3	.1
	77	1.7	2.9
	73	−2.3	5.3
	76	.7	.5
	79	3.7	13.7
	75	− .3	.1
	74	−1.3	1.7
	69	−6.3	39.7
	70	−5.3	28.1†
	75	− .3	.1
	70	−5.3	28.1
	70	−5.3	28.1
	78	2.7	7.3
	77	1.7	2.9
	70	−5.3	28.1
	73	−2.3	5.3
	76	.7	.5
	78	2.7	7.3
	72	−3.3	10.9
	76	.7	.5
	76	.7	.5
	70	−5.3	28.1
	76	.7	.5
	77	1.7	2.9**
otal..	3763	140.4	644.2

Calculations

$$M = \frac{3763}{50} = 75.3.$$

$$AD = \frac{\text{Sum of } d}{N} = \frac{140.4}{50} = 2.8.$$

$$SD = \sqrt{\frac{\text{Sum of } d^2}{N}} = \sqrt{\frac{644.2}{50}} = \sqrt{12.98} = 3.6.$$

$$PE_{(\text{Av.})} = \frac{.6745\ SD}{\sqrt{N}} = \frac{.6745 \times 3.6}{\sqrt{50}}$$

$$= \frac{.6745 \times 3.6}{7.07} = \frac{2.43}{7.07} = .34.$$

The average is $\frac{75.3}{.34}$, or 221.5 times the *PE*, and hence is reliable.

$$PE_{(SD)} = \frac{.6745\ SD}{\sqrt{2N}} = \frac{2.43}{\sqrt{100}} = \frac{2.43}{10} = .24.$$

The *SD* is $\frac{3.6}{.24}$, or 15 times the *PE*, and hence is reliable.

$$V = \frac{100 \times SD}{M} = \frac{100 \times 3.6}{75.3} = \frac{360}{75.3} = 4.8$$

Remarks by the Subject

* Confused on what letter follows *q*.

† Definite feeling of fatigue in hand; local in nature.

** Certain groups of letters are made as a unit. *S* expects to improve.

APPENDIX B.—NOTES FOR INSTRUCTORS AND MATERIALS FOR EXPERIMENTS

Notes for Instructors

Detailed information on the construction and use of apparatus is found in the standard experimental guides, and no attempt has been made to duplicate this material. The following books should be available in all laboratories.

Bills, Arthur Gilbert, *General experimental psychology.* New York: Longmans, Green & Co., 1934.

Fröbes, Joseph, *Lehrbuch der experimentellen psychologie,* volumes I and II. Freiburg: Herder & Co., 1917 and 1922.

Murchison, Carl (ed.), *The foundations of experimental psychology.* Worcester: Clark University Press, 1929.

Myers, Charles S., *A text-book of experimental psychology,* 3rd edition. Cambridge: Cambridge University Press, 1925.

Schulze, R., *Experimental psychology and pedagogy for teachers, normal colleges, and universities,* translated by Rudolph Pintner. New York: Macmillan Co., 1912.

Titchener, E. B., *Experimental psychology; a manual of laboratory practice,* 2 volumes in 4. New York: Macmillan Co., 1901-1905.

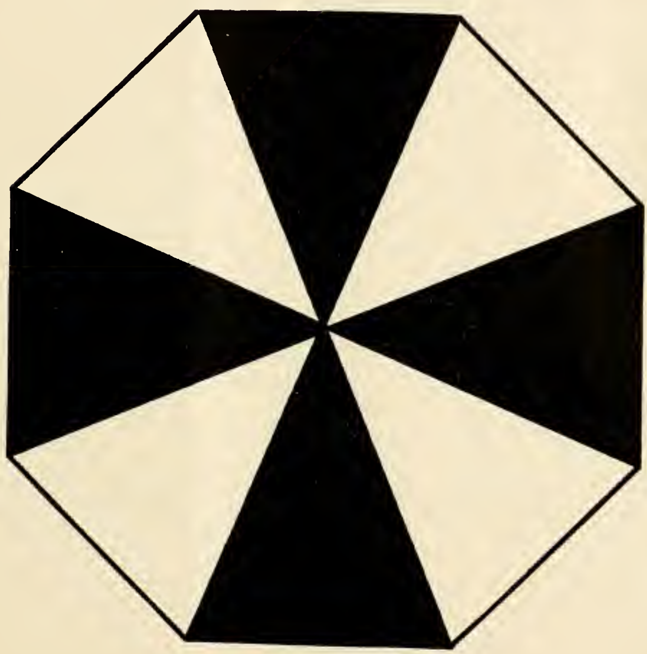
Whipple, Guy M., *Manual of mental and physical tests,* 2 parts. Baltimore: Warwick & York, 1915.

Instruments and supplies are procurable from the firms named below.

Marietta Apparatus Co., Marietta, Ohio.
C. H. Stoelting & Co., 424 North Homan Ave., Chicago, Ill.
Munsell Color Co., Baltimore, Md.
General Radio Co., Cambridge, Mass.

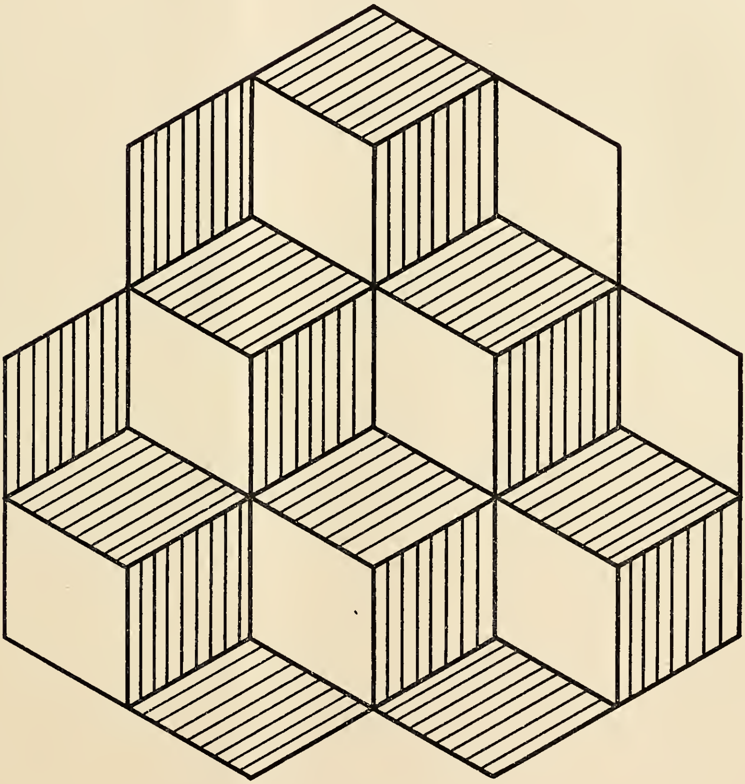
EXPERIMENT 28.—FLUCTUATION OF ATTENTION

PLATE A



EXPERIMENT 28.—FLUCTUATION OF ATTENTION

Plate B



Blank A

In the blank after each letter, write the figure given with the letter below, as explained in the description of the experiment.

a— 7	*c*—24	*e*—12	*g*—17	*i*—8	*k*—10	*m*—16
b—19	*d*— 3	*f*— 5	*h*—26	*j*—2	*l* —22	

i....c....g....m....a....k....d....h....b....j....e....l....c....i....f....m....h....b....j....e....l....g....d....k....a....f....

a....f....k....c....h....m....b....e....l....d....g....a....k....e....d....b....i....h....l....c....j....m....f....i....g....j....

m....d....h....e....a....j....f....c....k....b....l....i....c....m....j....e....l....a....g....i....d....h....b....g....k....f....

b....l....f....j....h....a....d....m....e....g....c....k....f....h....b....i....d....k....m....c....g....j....l....e....a....i....

g....d....i....c....f....k....b....h....a....j....e....l....i....m....l....g....a....j....e....h....b....m....f....c....k....d....

l....b....g....m....a....d....j....e....i....f....c....h....k....b....f....k....c....g....i....l....d....j....e....h....a....m....

k....e....h....b....l....i....c....a....k....g....j....f....d....m....b....g....l....i....e....c....h....a....m....d....j....f....

c....g....m....a....d....f....j....l....h....b....e....i....l....k....f....d....m....a....h....j....b....g....i....e....k....c....

h....e....b....k....c....m....d....a....i....f....l....j....g....a....l....f....b....i....k....c....h....e....d....j....g....m....

e....a....i....m....b....f....j....c....g....d....k....h....l....c....h....m....e....j....a....f....l....k....g....b....i....d....

d....h....l....c....e....k....m....i....f....a....g....b....j....a....l....c....i....f....d....e....j....m....h....g....k....b....

f....a....m....j....b....d....h....l....i....e....c....k....g....d....h....l....k....m....b....i....g....f....c....j....a....e....

[*Continued on reverse side*]

a—7	c—24	e—12	g—17	i—8	k—10	m—16
b—19	d—3	f—5	h—26	j—2	l—22	

j...l...e...h...c...a...m...f...b...k...g...i...d...a...m...c...f...i...h...e...k...b...l...d...g...j...

m...a...g...l...b...h...d...k...i...f...c...e...j...g...e...h...d...k...m...a...c...f...j...b...i...l...

i...c...k...f...e...m...a...g...l...d...b...h...c...i...m...a...f...e...j...l...h...d...b...j...g...k...

e...h...l...a...c...j...d...f...k...m...g...b...j...a...d...g...l...c...h...f...k...i...m...e...i...b...

a...f...j...m...b...g...k...e...i...c...d...l...h...m...h...d...a...i...e...b...l...g...j...c...f...k...

l...d...c...i...e...f...m...a...j...g...b...h...k...a...f...j...m...c...h...k...d...e...b...i...l...g...

h...m...j...f...b...k...d...h...l...a...e...c...g...i...c...e...k...a...m...b...i...l...g...d...f...j...

d...k...a...m...g...l...b...i...c...f...j...e...h...a...f...j...d...i...h...e...g...k...b...m...c...l...

k...h...e...b...l...i...c...a...k...g...j...f...d...m...b...g...l...i...c...e...a...h...m...d...j...f...

f...m...a...j...d...b...h...l...i...e...c...k...g...h...d...l...m...k...b...g...i...f...j...c...e...a...

b...l...f...d...h...a...m...j...c...g...e...h...f...k...i...b...d...g...c...m...k...i...a...e...l...j...

j...h...e...c...l...k...b...f...m...a...d...i...g...c...f...h...m...i...a...e...l...b...j...g...d...k...

g...i...f...d...h...c...a...j...b...e...k...m...l...i...g...a...j...e...l...k...d...c...f...m...b...h...

c...m...g...a...f...d...b...l...h...j...e...i...d...f...k...m...l...h...a...g...e...b...i...k...c...j...

a...k...f...c...b...m...h...e...d...l...g...a...k...e...b...d...i...c...j...l...h...m...j...g...f...i...

l...g...b...m...d...a...j...i...f...e...k...c...h...f...c...g...b...k...h...m...a...i...l...d...j...e...

EXPERIMENT 33.—ASSOCIATIVE LEARNING

BLANK B

In the blank after each letter, write the figure given with the letter below, as explained in the description of the experiment.

n—23	*p*—20	*r*—9	*t*—13	*v*—18	*x*—21	*z*—15
o—14	*q*— 1	*s*—4	*u*—25	*w*—11	*y*— 6	

t...... x...... o...... s...... v...... y...... p...... n...... w...... z...... q...... u...... r...... x...... s...... o...... v...... n...... y...... t...... q...... z...... u...... w...... r...... p......

z...... n...... r...... w...... q...... t...... o...... x...... s...... u...... y...... p...... v...... n...... z...... t...... q...... w...... r...... u...... p...... o...... x...... s...... v...... y......

n...... v...... p...... s...... y...... u...... z...... r...... t...... w...... o...... q...... x...... p...... u...... s...... n...... y...... v...... z...... x...... r...... w...... t...... q...... o......

s...... z...... q...... w...... o...... r...... n...... y...... p...... v...... t...... x...... u...... o...... z...... t...... w...... q...... y...... r...... v...... n...... p...... s...... u...... x......

o...... t...... x...... n...... r...... w...... z...... q...... v...... p...... y...... u...... s...... x...... q...... v...... o...... s...... z...... n...... u...... p...... w...... t...... y...... r......

x...... p...... s...... z...... v...... n...... t...... y...... o...... r...... w...... q...... v...... u...... z...... n...... u...... x...... r...... q...... w...... o...... s...... y...... t...... p......

q...... w...... n...... u...... r...... x...... o...... s...... z...... p...... v...... t...... y...... q...... t...... w...... o...... n...... v...... y...... p...... r...... x...... u...... z...... s......

v...... y...... s...... x...... o...... u...... p...... r...... w...... q...... t...... z...... n...... v...... p...... y...... u...... s...... x...... o...... t...... w...... r...... q...... n...... z......

w...... u...... n...... p...... v...... s...... q...... y...... r...... x...... o...... u...... p...... t...... z...... x...... v...... y...... t...... n...... r...... q...... o...... z...... w...... s......

p...... z...... w...... r...... u...... t...... n...... v...... o...... q...... y...... s...... x...... r...... u...... q...... z...... w...... n...... p...... y...... v...... s...... x...... t...... o......

u...... s...... n...... y...... v...... z...... x...... r...... w...... t...... o...... q...... n...... p...... s...... v...... y...... r...... z...... u...... t...... w...... o...... p...... x...... q......

r...... w...... y...... t...... p...... u...... n...... z...... s...... o...... v...... x...... s...... u...... q...... z...... r...... w...... p...... n...... v...... q...... y...... x...... o...... t......

[*Continued on reverse side*]

n—23 *p*—20 *r*—9 *t*—13 *v*—18 *x*—21 *z*—15
o—14 *q*— 1 *s*—4 *u*—25 *w*—11 *y*— 6

y	t	p	s	o	w	r	q	x	u	n	z	w	v	r	o	q	u	y	t	x	s	p	z	v	n
n	w	u	z	q	t	v	s	y	p	r	o	x	n	s	u	y	x	p	v	z	o	r	t	q	w
x	z	p	v	s	n	y	o	t	r	w	q	u	z	v	n	p	t	y	o	s	w	q	r	x	u
t	o	x	n	p	w	v	s	y	q	z	r	x	o	u	s	y	v	n	q	z	t	r	u	w	p
p	r	w	z	u	n	t	o	v	x	s	y	q	z	r	p	u	w	s	x	q	n	o	t	v	y
z	n	x	o	s	r	w	q	t	u	o	p	v	t	n	y	z	r	w	q	u	y	v	p	s	x
s	q	r	w	z	o	y	n	p	t	v	x	u	z	o	w	t	q	y	x	p	r	s	u	n	v
v	o	y	s	x	u	p	w	r	z	q	n	t	y	v	p	u	s	o	t	n	x	w	z	q	r
r	x	u	q	w	o	s	y	t	p	n	v	z	u	q	w	r	t	p	v	x	s	n	o	y	z
w	p	n	v	s	u	r	x	q	y	o	p	u	t	z	v	n	x	y	t	o	z	w	r	q	s
o	z	t	w	r	n	x	v	p	s	u	y	q	x	o	s	q	r	w	z	v	n	y	p	t	u
y	p	o	r	q	u	z	n	z	x	v	p	s	t	y	u	v	o	q	r	t	s	w	x	n	w
q	n	w	u	r	x	o	s	p	v	z	y	t	s	z	x	r	p	u	n	v	y	t	o	w	q
u	x	p	o	q	w	t	u	z	r	p	s	v	y	n	q	o	t	w	r	x	z	v	s	y	n
z	q	n	r	w	t	o	s	x	u	y	x	p	v	z	t	n	w	q	u	p	o	r	y	s	v
n	u	s	v	p	r	x	y	q	y	t	w	o	z	u	x	v	t	p	n	s	q	w	z	r	o

EXPERIMENT 37.—KNOWLEDGE OF WORDS

1. a *lucid* stream: (*a*) rippling; (*b*) fresh; (*c*) hidden; (*d*) clear........ (..........)
2. to *exhort* a friend: (*a*) urge; (*b*) applaud; (*c*) favor; (*d*) protect.... (..........)
3. showing great *fortitude:* (*a*) skill; (*b*) resolute endurance; (*c*) aptness; (*d*) generosity.. (..........)
4. a *denizen* of a new state: (*a*) code; (*b*) inhabitant; (*c*) recognized privilege; (*d*) crime against unwritten law........................ (..........)
5. a *frugal* housewife: (*a*) productive; (*b*) tidy; (*c*) agreeable; (*d*) saving (..........)
6. to incur *enmity:* (*a*) debt; (*b*) hostility; (*c*) danger; (*d*) responsibility (..........)
7. *propitious* events: (*a*) foreboding; (*b*) dangerous; (*c*) favorable; (*d*) meaningful.. (..........)
8. to use a *cudgel:* (*a*) club; (*b*) foreign phrase; (*c*) bribe; (*d*) expressive word.. (..........)
9. a *sordid* bargain: (*a*) one-sided; (*b*) unprofitable; (*c*) ignoble; (*d*) illegal.. (..........)
10. to *ostracize* a person: (*a*) try in military court; (*b*) banish; (*c*) falsely accuse; (*d*) reward.................................. (..........)
11. an *ignoble* deed: (*a*) unnatural; (*b*) unexplainable; (*c*) selfish; (*d*) base (..........)
12. a *formidable* army: (*a*) well-organized; (*b*) trained; (*c*) alarming; (*d*) victorious.. (..........)
13. *exuberant* vitality: (*a*) overflowing; (*b*) newly acquired; (*c*) exhausted; (*d*) formerly possessed.......................... (..........)
14. the *atrophy* of a muscle: (*a*) stiffening; (*b*) wasting; (*c*) enlargement; (*d*) sudden contraction.................................. (..........)
15. executing rapid *gyrations:* (*a*) scrolls; (*b*) foils; (*c*) dagger thrusts; (*d*) revolutions.. (..........)
16. a *refractory* horse: (*a*) spirited; (*b*) ill-tempered; (*c*) obstinate; (*d*) docile.. (..........)
17. an *extortionate* price: (*a*) advertised; (*b*) minimum; (*c*) excessive; (*d*) competitive.. (..........)
18. a *morose* disposition: (*a*) uneven; (*b*) contentious; (*c*) fiery; (*d*) sullen (..........)
19. *indolent* by nature: (*a*) abusive; (*b*) idle; (*c*) violent; (*d*) sullen..... (..........)
20. the *indigent* man: (*a*) haughty; (*b*) needy; (*c*) unsettled; (*d*) independent.. (..........)

21. to *elucidate* a matter: (*a*) postpone; (*b*) evade; (*c*) confuse by explaining; (*d*) clarify . . . . (........

22. the *sagacity* of the aged: (*a*) decline; (*b*) philosophy; (*c*) calmness; (*d*) wisdom . . . . (........

23. an *impetuous* charge: (*a*) inappropriate; (*b*) furious; (*c*) carefully planned; (*d*) important . . . . (........

24. to *emulate* a person: (*a*) strive to excel; (*b*) mistrust; (*c*) injure maliciously; (*d*) praise . . . . (........

25. to *sully* a character: (*a*) berate; (*b*) influence; (*c*) mold; (*d*) tarnish (........

26. a savage's *amulet:* (*a*) omen; (*b*) charm; (*c*) weapon; (*d*) ceremony . . (........

27. a *ludicrous* encounter: (*a*) grotesque; (*b*) producing embarrassment; (*c*) vicious; (*d*) faked . . . . (........

28. *perfunctory* observances: (*a*) uncommon; (*b*) indifferent; (*c*) unpopular; (*d*) required . . . . (........

29. an *anomalous* specimen: (*a*) valuable; (*b*) rare; (*c*) abnormal; (*d*) incorrectly identified . . . . (........

30. a *paradoxical* assertion: (*a*) unproven; (*b*) plagiarized; (*c*) self-contradictory; (*d*) unacceptable . . . . (........

31. the *repercussion* of the boom: (*a*) return effect; (*b*) recurrence, (*c*) abundance; (*d*) accurate description . . . . (........

32. *wanton* victors: (*a*) unbearable; (*b*) reckless; (*c*) merciful; (*d*) celebrating . . . . (........

33. his *exemplar* was the captain himself: (*a*) trainer; (*b*) accuser; (*c*) model; (*d*) nemesis . . . . (........

34. held in *abeyance:* (*a*) high regard; (*b*) suspense; (*c*) subordinate position; (*d*) as security . . . . (........

35. the will *stipulates:* (*a*) agrees; (*b*) supplants; (*c*) binds; (*d*) specifies (........

36. an *incisive* statement: (*a*) trenchant; (*b*) brief; (*c*) final; (*d*) frank . . . (........

37. a *tacit* agreement: (*a*) limited; (*b*) temporary; (*c*) illegal; (*d*) implied (........

38. *vicissitudes* of fortune: (*a*) discomforts; (*b*) irregular changes; (*c*) blessings; (*d*) vanities . . . . (........

39. a *parsimonious* person: (*a*) ecclesiastical; (*b*) sedate; (*c*) haughty; (*d*) niggardly . . . . (........

40. a *taciturn* person: (*a*) easily angered; (*b*) disloyal; (*c*) reticent; (*d*) obstinate . . . . (........

41. the *fecundity* of certain species: (*a*) fertility; (*b*) characteristics; (*c*) offensiveness; (*d*) life span .... (..........)

42. a *despicable* act: (*a*) admirable; (*b*) contemptible; (*c*) enraging; (*d*) revengeful .... (..........)

43. to *cajole* a person: (*a*) coax with flattery; (*b*) render powerless; (*c*) ridicule; (*d*) tease .... (..........)

44. to *alleviate* distress: (*a*) aggravate; (*b*) ignore; (*c*) mitigate; (*d*) share (..........)

45. a *prodigious* undertaking: (*a*) unusual; (*b*) huge; (*c*) grave; (*d*) highly promising .... (..........)

46. to act with *alacrity:* (*a*) cheerfulness; (*b*) briskness; (*c*) gravity; (*d*) solemnity .... (..........)

47. a *fictitious* story: (*a*) romantic; (*b*) dramatic; (*c*) impossible; (*d*) invented .... (..........)

48. to *palliate* a disease: (*a*) endure; (*b*) dread; (*c*) feign; (*d*) mitigate.. (..........)

49. he *jeopardized* his life: (*a*) imperiled; (*b*) guarded; (*c*) sacrificed; (*d*) offered .... (..........)

50. the *harbinger* of pain: (*a*) definite location; (*b*) precursor; (*c*) cause; (*d*) discomfort .... (..........)

51. to *reiterate* an explanation: (*a*) retract; (*b*) revise; (*c*) repeat; (*d*) reconsider .... (..........)

52. the *jurisdiction* of the state: (*a*) codified laws; (*b*) controlling authority; (*c*) lawful trials; (*d*) appealed cases .... (..........)

53. *insipid* fruit: (*a*) imported; (*b*) rarely used; (*c*) tropical; (*d*) flat in taste .... (..........)

54. to *succor* a stranger: (*a*) welcome; (*b*) register; (*c*) misjudge; (*d*) assist (..........)

55. an *obsequious* manner: (*a*) devoted; (*b*) attentive; (*c*) cringing; (*d*) gallant .... (..........)

56. *sundry* facts: (*a*) gloomy; (*b*) uninteresting; (*c*) various; (*d*) secret (..........)

57. *succinct* phraseology: (*a*) concise; (*b*) expressive; (*c*) euphonious; (*d*) of mixed language .... (..........)

58. governmental *subvention:* (*a*) indebtedness; (*b*) help; (*c*) organization; (*d*) policy .... (..........)

59. a *scintillating* stone: (*a*) sparkling; (*b*) disintegrating; (*c*) becoming darker; (*d*) used for polishing .... (..........)

60. an *adroit* politician: (*a*) unprincipled; (*b*) strong; (*c*) with right principles; (*d*) clever .... (..........)

61. a *recalcitrant* tribe: (*a*) conquered; (*b*) refractory; (*c*) victorious; (*d*) of mixed blood. . . . . (........

62. an *infallible* source of knowledge: (*a*) unerring; (*b*) inconceivable; (*c*) unsuspected; (*d*) forbidden . . . . (........

63. a *pernicious* book: (*a*) poorly written; (*b*) injurious; (*c*) purposeful; (*d*) tactless . . . . (........

64. *retaliation* for injuries: (*a*) atonement; (*b*) compensation; (*c*) enter suit; (*d*) reprisal. . . . . (........

65. the *antithesis* of belief and practice: (*a*) opposition; (*b*) accepted theories; (*c*) deductions; (*d*) principles. . . . . (........

66. an *astute* representative: (*a*) unreasonable; (*b*) powerful; (*c*) sagacious; (*d*) stupid. . . . . (........

67. a *supercilious* manner: (*a*) humble; (*b*) disdainful; (*c*) cringing; (*d*) engaging . . . . (........

68. *sardonic* humor: (*a*) droll; (*b*) good-natured; (*c*) sneering; (*d*) spasmodic . . . . (........

69. their *vaunted* lineage: (*a*) boasted of; (*b*) hidden; (*c*) pure; (*d*) ancient (........

70. *esculent* roots: (*a*) fibrous; (*b*) tropical; (*c*) edible; (*d*) knotty. . . . . . (........

71. *occult* beliefs: (*a*) based on evidence; (*b*) ancient; (*c*) discarded; (*d*) mysterious . . . . (........

72. the *legacy* of his father: (*a*) title; (*b*) bequest; (*c*) business insight; (*d*) policy . . . . (........

73. the *consternation* of the group: (*a*) amazement; (*b*) disorganization; (*c*) determination; (*d*) deliberate decision. . . . . (........

74. a *debonair* prince: (*a*) witty; (*b*) brunette; (*c*) affable; (*d*) energetic (........

75. the outcome *chagrined* him: (*a*) amused; (*b*) puzzled; (*c*) mortified; (*d*) sickened . . . . (........

76. a *judicious* teacher: (*a*) legalistic; (*b*) discreet; (*c*) unfair; (*d*) prejudiced. . . . . (........

77. an impressive *mien:* (*a*) sight; (*b*) bearing; (*c*) boundary; (*d*) ceremony. . . . . (........

78. a *sequestered* region: (*a*) unsettled; (*b*) celebrated; (*c*) unproductive; (*d*) secluded . . . . (........

79. to *eschew* evil: (*a*) disapprove; (*b*) seek; (*c*) condemn; (*d*) avoid. . . . (........

80. a *suave* manner: (*a*) easy and agreeable; (*b*) abrupt; (*c*) insincere; (*d*) hypocritical. . . . . (........

81. to *abrogate* rights: (*a*) abolish; (*b*) reinforce; (*c*) modify; (*d*) delegate to another. . . . . (........

82. a *cursory* reader: (*a*) efficient; (*b*) critical; (*c*) superficial; (*d*) fault-finding.. (..........)

83. an *incorrigible* thief: (*a*) detestable; (*b*) irreclaimable; (*c*) sneaky; (*d*) crafty.. (..........)

84. the *exigency* before us: (*a*) prescribed business; (*b*) unexpected problem; (*c*) routine matter; (*d*) pressing necessity.................. (..........)

85. *precarious* popularity: (*a*) uncertain; (*b*) dangerous; (*c*) well-founded; (*d*) unbelievable.. (..........)

86. *prognostic* indications of a disease: (*a*) correctable; (*b*) fatal; (*c*) disturbing; (*d*) foreshadowing.. (..........)

87. a *veneered* civility: (*a*) venerated; (*b*) glossed over; (*c*) studied; (*d*) unrecognized.. (..........)

88. the *emoluments* of an office: (*a*) non-prescribed duties; (*b*) annoyances; (*c*) remunerations; (*d*) routine duties.................. (..........)

89. *evanescent* pleasures: (*a*) vanishing; (*b*) colorful; (*c*) sensible; (*d*) lasting.. (..........)

90. to *discommode* a neighbor: (*a*) accommodate; (*b*) inconvenience; (*c*) disregard; (*d*) berate.. (..........)

91. *incipient* despotism perished: (*a*) cruel; (*b*) hidden; (*c*) openly planned; (*d*) beginning.. (..........)

92. *vicarious* suffering: (*a*) substitutionary; (*b*) continuous; (*c*) depressing; (*d*) resigned.. (..........)

93. to *foment* a dispute: (*a*) settle; (*b*) instigate; (*c*) delay; (*d*) dispose of by legal means.. (..........)

94. a *moribund* enterprise: (*a*) dubious; (*b*) stealthy; (*c*) dying; (*d*) expanding.. (..........)

95. a *propensity* for an art: (*a*) dislike; (*b*) bent; (*c*) finished skill; (*d*) opportunity for training.. (..........)

96. a *resilient* force: (*a*) powerful; (*b*) uncontrollable; (*c*) cumulative; (*d*) elastic.. (..........)

97. to *meliorate* nature with art: (*a*) improve; (*b*) regulate; (*c*) oppose; (*d*) displace.. (..........)

98. a *dilatory* report: (*a*) illegal; (*b*) showy but unsound; (*c*) voluminous; (*d*) tardy.. (..........)

99. *sublunary* affairs: (*a*) wicked; (*b*) worldly; (*c*) held in secret; (*d*) irrational.. (..........)

100. *empirical* conclusions: (*a*) insecure; (*b*) derived from observation; (*c*) theoretical; (*d*) temporary in nature . . . . (..........

101. a literary *milieu:* (*a*) environment; (*b*) standard; (*c*) style; (*d*) impression . . . . (..........

102. he attacked with strange *fatuity:* (*a*) unreasonable thoroughness; (*b*) blind fury; (*c*) unconscious stupidity; (*d*) sense of failure . . . . (..........

103. *rococo* ornamentation: (*a*) imitative; (*b*) massed black and white; (*c*) lifeless; (*d*) fantastic . . . . (..........

104. a *dilettante* in art: (*a*) severe critic; (*b*) patron; (*c*) amateur; (*d*) fashionable style . . . . (..........

105. display *comity* in human relations: (*a*) aloofness; (*b*) good breeding; (*c*) tolerance; (*d*) joviality . . . . (..........

106. under the imperial *ægis:* (*a*) rule; (*b*) protection; (*c*) special command; (*d*) seal . . . . (..........

107. a *congeries* of races: (*a*) mixture; (*b*) melting-pot; (*c*) aggregation: (*d*) intermarriage . . . . (..........

108. to *allocate* duties: (*a*) reduce; (*b*) share; (*c*) liberate from; (*d*) allot (..........

109. to *extenuate* crime: (*a*) increase; (*b*) palliate; (*c*) condemn; (*d*) oppose (..........

110. an *expedient* solution: (*a*) clever; (*b*) advantageous; (*c*) intricate; (*d*) clear . . . . (..........

111. a *sedulous* worker: (*a*) diligent; (*b*) halfhearted; (*c*) cautious; (*d*) stirring up strife . . . . (..........

112. a *pandemic* disease: (*a*) incurable; (*b*) recurring after apparent cure; (*c*) mild; (*d*) always present . . . . (..........

113. *reticulated* work: (*a*) netted; (*b*) done meticulously; (*c*) sub-contracted; (*d*) approved provisionally . . . . (..........

114. an *umbrageous* proposal: (*a*) insulting; (*b*) suspicious; (*c*) made with right to withdraw; (*d*) wholly unexpected . . . . (..........

115. *littoral* trade: (*a*) scattered; (*b*) frequenting the shore; (*c*) in small articles; (*d*) long established . . . . (..........

116. a showy *sporran:* (*a*) purse; (*b*) belt; (*c*) flower; (*d*) metal ornament (..........

117. *intransigent* members of an order: (*a*) of lower class; (*b*) in process of being advanced; (*c*) fraternal; (*d*) irreconcilable . . . . (..........

118. the *synergy* of the organs: (*a*) devitalization; (*b*) recovery; (*c*) correlation of action; (*d*) gross structure . . . . (..........

119. *sequacious* thinkers: (*a*) talkative; (*b*) obscure; (*c*) adhering; (*d*) antiquated . . . . (..........

120. the *rodomontade* of the traveler: (*a*) stammering; (*b*) lofty bragging; (*c*) awkward gestures; (*d*) correct but foreign speech . . . . (..........

EXPERIMENT 37.—KNOWLEDGE OF WORDS

Key For Checking Answers

1. *d*	31. *a*	61. *b*	91. *d*
2. *a*	32. *b*	62. *a*	92. *a*
3. *b*	33. *c*	63. *b*	93. *b*
4. *b*	34. *b*	64. *d*	94. *c*
5. *d*	35. *d*	65. *a*	95. *b*
6. *b*	36. *a*	66. *c*	96. *d*
7. *c*	37. *d*	67. *b*	97. *a*
8. *a*	38. *b*	68. *c*	98. *d*
9. *c*	39. *d*	69. *a*	99. *b*
10. *b*	40. *c*	70. *c*	100. *b*
11. *d*	41. *a*	71. *d*	101. *a*
12. *c*	42. *b*	72. *b*	102. *c*
13. *a*	43. *a*	73. *a*	103. *d*
14. *b*	44. *c*	74. *c*	104. *c*
15. *d*	45. *b*	75. *c*	105. *b*
16. *c*	46. *b*	76. *b*	106. *b*
17. *c*	47. *d*	77. *b*	107. *c*
18. *d*	48. *d*	78. *d*	108. *d*
19. *b*	49. *a*	79. *d*	109. *b*
20. *b*	50. *b*	80. *a*	110. *b*
21. *d*	51. *c*	81. *a*	111. *a*
22. *d*	52. *b*	82. *c*	112. *d*
23. *b*	53. *d*	83. *b*	113. *a*
24. *a*	54. *d*	84. *d*	114. *b*
25. *d*	55. *c*	85. *a*	115. *b*
26. *b*	56. *c*	86. *d*	116. *a*
27. *a*	57. *a*	87. *b*	117. *d*
28. *b*	58. *b*	88. *c*	118. *c*
29. *c*	59. *a*	89. *a*	119. *c*
30. *c*	60. *d*	90. *b*	120. *b*

EXPERIMENT 39.—DISCOVERING RELATIONS: REASONING

1. 8 7 3 2 = 6
2. 9 7 5 3 = 13
3. 7 1 2 9 = 12
4. 8 4 6 6 = 18
5. 7 3 3 4 = 22
6. 9 9 2 6 = 14
7. 5 5 3 6 = 24
8. 7 3 4 6 = 19
9. 8 1 1 2 = 20
10. 6 6 5 3 = 15
11. 5 6 8 2 = 11
12. 2 3 5 5 = 35
13. 4 3 5 7 = 12
14. 5 6 7 8 = 31
15. 7 9 3 8 = 27
16. 4 4 3 8 = 21
17. 3 5 1 6 = 13
18. 6 3 4 2 = 16
19. 4 8 2 7 = 13
20. 8 7 1 6 = 12
21. 9 6 2 4 = 10
22. 6 4 5 5 = 20
23. 8 2 1 6 = 30
24. 4 2 5 6 = 19
25. 3 8 4 4 = 10
26. 8 6 4 3 = 24
27. 9 4 6 1 = 30
28. 4 4 3 8 = 40
29. 9 9 4 2 = 20
30. 6 3 4 4 = 12
31. 2 4 2 2 = 14
32. 6 5 3 2 = 16
33. 3 7 2 4 = 20
34. 3 2 5 3 = 27
35. 5 7 2 3 = 11
36. 5 5 9 3 = 13
37. 7 3 2 2 = 16
38. 8 9 1 3 = 6
39. 1 5 3 8 = 16
40. 6 6 6 6 = 7
41. 5 9 2 3 = 21
42. 9 4 9 3 = 11
43. 8 1 3 7 = 17
44. 2 3 5 6 = 4
45. 4 2 8 8 = 24
46. 4 3 8 2 = 18
47. 2 6 8 4 = 60
48. 4 3 3 8 = 29
49. 5 8 7 4 = 5
50. 9 1 2 1 = 6
51. 3 4 6 1 = 3
52. 8 8 2 3 = 59
53. 7 5 3 1 = 3
54. 4 4 2 4 = 20
55. 8 9 7 8 = 32
56. 2 9 7 3 = 8
57. 6 7 9 1 = 4
58. 7 5 6 4 = 37
59. 3 4 6 4 = 22
60. 5 4 6 8 = 7
61. 3 2 4 6 = 4
62. 6 3 9 6 = 3
63. 2 4 6 7 = 21
64. 8 9 8 8 = 8
65. 5 7 3 1 = 5
66. 5 5 2 3 = 4
67. 9 2 4 1 = 21
68. 9 6 1 1 = 1
69. 8 4 7 2 = 7
70. 9 9 9 1 = 3
71. 3 4 6 2 = 9
72. 6 1 5 8 = 4
73. 9 7 4 2 = 22
74. 9 7 8 1 = 3
75. 5 9 4 3 = 6
76. 5 4 7 8 = 2
77. 2 4 6 8 = 4
78. 9 8 4 3 = 7
79. 5 5 3 7 = 0
80. 8 3 6 1 = 5
81. 8 4 9 6 = 35
82. 7 8 5 2 = 6
83. 3 7 6 8 = 2
84. 2 3 7 6 = 2
85. 9 3 7 7 = 3
86. 8 4 9 3 = 6
87. 7 7 7 7 = 8
88. 4 7 1 5 = 7
89. 8 3 3 2 = 7
90. 9 8 7 6 = 4
91. 4 7 1 3 = 9
92. 9 4 3 6 = 2
93. 6 9 5 4 = 12
94. 1 9 5 2 = 30
95. 5 3 2 1 = 5
96. 4 1 8 3 = 43
97. 2 7 1 9 = 6
98. 8 6 7 4 = 8
99. 7 8 5 6 = 9
100. 5 4 9 7 = 4
101. 9 4 6 8 = 38
102. 8 6 4 2 = 3
103. 6 4 2 2 = 6
104. 5 3 2 3 = 16
105. 5 5 8 1 = 10
106. 9 6 5 4 = 11
107. 8 4 1 7 = 21
108. 5 3 4 6 = 14
109. 4 3 7 9 = 16
110. 2 3 8 9 = 49
111. 4 5 7 3 = 16
112. 5 5 1 8 = 18
113. 6 5 7 9 = 28
114. 9 3 4 5 = 17
115. 5 4 8 6 = 34
116. 7 6 9 6 = 15
117. 8 7 6 5 = 45
118. 9 6 8 5 = 35
119. 9 3 2 8 = 14
120. 7 4 3 8 = 23
121. 7 7 8 4 = 10
122. 6 3 4 7 = 15
123. 3 5 3 5 = 19
124. 9 8 3 3 = 23
125. 7 8 8 9 = 14
126. 7 5 3 9 = 15
127. 8 7 3 6 = 30
128. 9 3 1 7 = 28
129. 4 4 3 3 = 2
130. 5 5 3 2 = 11
131. 7 4 4 2 = 16
132. 6 3 7 2 = 12
133. 9 4 3 3 = 11
134. 5 4 3 5 = 15
135. 4 7 2 3 = 10
136. 9 8 9 2 = 18
137. 6 3 9 2 = 20
138. 7 3 2 2 = 7
139. 8 3 1 2 = 6
140. 1 8 3 3 = 1
141. 3 3 3 1 = 8
142. 2 9 6 2 = 15
143. 3 7 1 8 = 17
144. 7 9 4 5 = 60
145. 6 4 1 5 = 14
146. 6 3 3 5 = 60
147. 7 5 9 4 = 22
148. 9 3 6 8 = 1
149. 3 8 1 3 = 8
150. 9 3 6 1 = 17

Key to Exercises

1.	−	×	×	51.	×	÷	+	101.	−	×	+
2.	−	×	+	52.	×	−	−	102.	−	+	÷
3.	−	÷	+	53.	+	÷	−	103.	+	+	÷
4.	−	×	−	54.	+	×	+	104.	×	−	+
5.	×	−	+	55.	+	+	+	105.	÷	+	+
6.	+	+	−	56.	×	−	−	106.	−	×	−
7.	÷	+	×	57.	+	−	×	107.	÷	+	×
8.	×	+	−	58.	×	+	−	108.	−	×	+
9.	+	+	×	59.	×	+	+	109.	−	×	+
10.	−	+	×	60.	+	+	−	110.	+	×	+
11.	×	−	÷	61.	×	×	÷	111.	×	−	+
12.	×	×	+	62.	÷	×	÷	112.	×	+	−
13.	−	×	+	63.	×	+	+	113.	×	+	−
14.	×	−	+	64.	×	−	÷	114.	÷	×	+
15.	+	+	+	65.	+	÷	+	115.	×	+	+
16.	×	−	+	66.	+	+	÷	116.	−	×	+
17.	+	−	+	67.	×	+	−	117.	×	−	−
18.	÷	×	×	68.	−	−	−	118.	+	−	×
19.	+	÷	+	69.	÷	×	÷	119.	÷	×	+
20.	−	+	×	70.	+	÷	+	120.	×	+	−
21.	−	×	+	71.	×	+	÷	121.	+	−	+
22.	+	+	+	72.	+	+	−	122.	÷	×	+
23.	÷	+	×	73.	+	+	+	123.	+	×	−
24.	×	+	+	74.	+	÷	+	124.	+	+	+
25.	×	÷	+	75.	+	+	÷	125.	+	+	−
26.	−	×	×	76.	+	+	÷	126.	−	×	+
27.	−	×	×	77.	+	+	−	127.	+	÷	×
28.	+	−	×	78.	+	+	÷	128.	÷	+	×
29.	+	+	−	79.	+	−	−	129.	+	−	−
30.	÷	×	+	80.	+	−	×	130.	×	−	÷
31.	×	×	−	81.	×	+	−	131.	×	+	÷
32.	+	+	+	82.	+	÷	×	132.	÷	×	−
33.	+	÷	×	83.	+	+	÷	133.	×	−	÷
34.	×	×	−	84.	+	+	÷	134.	+	÷	×
35.	×	−	÷	85.	÷	×	÷	135.	+	+	−
36.	÷	+	+	86.	÷	×	÷	136.	−	×	×
37.	+	−	×	87.	×	+	÷	137.	+	+	+
38.	+	+	÷	88.	+	+	−	138.	+	÷	+
39.	+	÷	×	89.	+	+	÷	139.	+	+	÷
40.	×	+	÷	90.	+	+	÷	140.	+	÷	÷
41.	+	÷	×	91.	+	+	−	141.	+	+	−
42.	−	+	−	92.	−	+	−	142.	+	+	−
43.	−	+	+	93.	+	÷	×	143.	+	−	+
44.	+	+	−	94.	+	+	×	144.	+	−	×
45.	−	×	+	95.	+	÷	+	145.	+	−	+
46.	×	+	−	96.	+	×	+	146.	+	+	×
47.	+	×	−	97.	×	+	−	147.	−	×	+
48.	+	×	+	98.	+	÷	×	148.	÷	+	−
49.	+	+	÷	99.	+	÷	+	149.	+	×	−
50.	×	−	−	100.	×	−	−	150.	÷	×	−

EXPERIMENT 40.—KENT-ROSANOFF ASSOCIATION TEST

Stimulus	Response	f	Stimulus	Response	f
1. table			26. wish		
2. dark			27. river		
3. music			28. white		
4. sickness			29. beautiful		
5. man			30. window		
6. deep			31. rough		
7. soft			32. citizen		
8. eating			33. foot		
9. mountain			34. spider		
10. house			35. needle		
11. black			36. red		
12. mutton			37. sleep		
13. comfort			38. anger		
14. hand			39. carpet		
15. short			40. girl		
16. fruit			41. high		
17. butterfly			42. working		
18. smooth			43. sour		
19. command			44. earth		
20. chair			45. trouble		
21. sweet			46. soldier		
22. whistle			47. cabbage		
23. woman			48. hard		
24. cold			49. eagle		
25. slow			50. stomach		

[*Continued on reverse side*]

Stimulus	Response	f	Stimulus	Response	f
51. stem			76. bitter		
52. lamp			77. thirsty		
53. dream			78. hammer		
54. yellow			79. city		
55. bread			80. square		
56. justice			81. butter		
57. boy			82. doctor		
58. light			83. loud		
59. health			84. thief		
60. Bible			85. lion		
61. memory			86. joy		
62. sheep			87. bed		
63. bath			88. heavy		
64. cottage			89. tobacco		
65. swift			90. baby		
66. blue			91. moon		
67. hungry			92. scissors		
68. priest			93. quiet		
69. ocean			94. green		
70. head			95. salt		
71. stove			96. street		
72. long			97. king		
73. religion			98. cheese		
74. whiskey			99. blossom		
75. child			100. afraid		

Average frequency........................

EXPERIMENT 42.—MEMORY SPAN

Parts A and B

I.

A (13) 2 5 3 9 4 6 9 2 8 5 9 1 6
B (5) 4 1 6 3 8
C (11) 6 2 9 6 1 4 8 3 5 8 3
D (7) 4 2 6 9 1 8 5
E (8) 4 1 9 3 5 8 2 6
F (9) 5 2 8 1 5 9 3 8 4
G (6) 2 9 5 3 6 8
H (12) 4 6 1 8 2 9 2 6 3 8 1 5
I (10) 8 2 6 9 4 6 3 8 5 1

II.

A (9) 6 2 5 8 4 9 3 1 8
B (11) 5 1 8 2 9 3 6 4 9 2 6
C (13) 4 8 5 2 6 9 2 4 1 3 6 1 4
D (5) 6 3 8 2 5
E (7) 6 4 9 2 8 3 8
F (12) 2 6 4 9 5 3 6 4 1 8 5 3
G (10) 5 1 4 8 2 9 6 3 5 2
H (8) 9 1 6 3 5 2 8 4
I (6) 4 1 8 3 9 5

III.

A (7) 9 5 3 1 4 8 2
B (12) 4 6 1 8 3 6 4 9 5 2 6 8
C (6) 4 2 9 3 1 5
D (13) 5 9 6 3 8 1 3 5 2 6 4 8 3
E (5) 8 3 9 6 4
F (11) 2 5 3 1 4 9 6 8 5 1 4
G (10) 4 9 5 2 8 3 6 1 9 6
H (8) 8 4 9 6 2 5 1 3
I (9) 8 4 1 6 9 5 3 6 2

IV.

A (11) 4 9 6 3 1 8 2 9 3 5 8
B (13) 3 6 4 1 5 8 1 3 9 4 3 5 2
C (5) 5 2 9 1 6
D (9) 2 5 9 4 1 6 3 8 4
E (7) 5 3 8 2 9 1 6
F (8) 5 2 6 1 3 9 4 8
G (6) 9 6 2 8 5 1
H (10) 6 4 9 3 1 8 2 5 9 4
I (12) 5 2 9 6 3 8 1 6 2 9 4 8

V.

A (8) 8 3 9 5 2 6 4 1
B (6) 3 1 8 2 9 6
C (12) 5 8 2 9 4 1 6 3 5 8 6 4
D (10) 2 5 8 1 3 6 2 9 4 8
E (13) 8 2 9 5 1 3 5 8 4 9 2 5 1
F (5) 2 6 3 5 8
G (11) 4 8 5 2 6 9 3 5 1 8 6
H (7) 2 8 4 8 5 9 3
I (9) 9 2 6 3 8 5 4 1 3

VI.

A (12) 3 5 9 6 2 5 8 4 1 6 9 4
B (8) 9 2 5 1 6 4 8 3
C (9) 9 6 2 5 8 4 1 6 3
D (6) 5 3 8 1 6 4
E (13) 6 1 8 4 9 4 2 6 3 1 5 8 2
F (10) 3 1 4 9 5 2 8 6 3 5
G (11) 3 6 4 9 2 5 8 1 4 6 3
H (7) 9 6 3 5 1 8 2
I (5) 5 2 9 6 4

VII.

A (6) 2 9 5 3 1 8
B (8) 2 8 1 6 9 5 3 8
C (10) 9 6 1 4 2 5 3 8 1 6
D (12) 8 1 4 2 6 4 1 5 9 6 8 3
E (9) 4 9 2 5 8 1 3 9 6
F (13) 9 3 1 6 4 6 2 9 5 2 8 3 9
G (5) 3 8 2 9 1
H (11) 5 9 6 8 3 9 4 1 6 2 8
I (7) 3 1 5 8 6 9 2

VIII.

A (9) 8 1 5 3 8 4 9 6 2
B (10) 8 3 6 2 5 9 4 1 6 2
C (8) 3 6 8 1 4 2 9 5
D (6) 6 4 9 2 5 3
E (12) 9 2 5 3 8 2 6 1 5 4 8 6
F (7) 8 5 2 6 3 1 4
G (13) 4 2 6 8 3 5 8 1 6 8 5 2 6
H (5) 4 9 2 6 3
I (11) 6 1 8 5 3 9 2 6 1 4 8

IX.

A (10) 5 9 2 6 3 8 1 4 9 3
B (7) 2 6 4 9 5 1 3
C (12) 6 9 3 1 5 8 6 9 1 4 2 5
D (11) 9 4 2 8 1 5 2 6 9 4 6
E (5) 9 5 2 8 3
F (8) 6 9 5 8 3 1 4 9
G (9) 6 3 9 5 2 4 8 3 1
H (6) 3 9 1 5 2 6
I (13) 4 6 2 1 5 8 4 3 9 2 6 5 3

X.

A (5) 3 9 5 6 2
B (10) 6 2 8 1 9 5 3 6 4 8
C (7) 3 8 5 1 9 6 4
D (11) 8 3 1 4 8 5 2 6 9 4 5
E (9) 3 1 8 6 4 9 6 2 5
F (6) 8 5 1 3 9 2
G (12) 3 5 8 5 1 8 2 9 6 1 4 2
H (13) 3 5 3 9 4 6 9 2 8 5 2 6 4
I (8) 2 5 3 6 9 4 8 1

EXPERIMENT 42.—MEMORY SPAN

Parts C and D

I.

A (13) b e c h d f h b g e h a f
B (5) d a f c g
C (11) f b h f a d g c e g c
D (7) d b f h a g e
E (8) d a h c e g b f
F (9) e b g a e h c g d
G (6) b h e c f g
H (12) d f a g b h b f c g a e
I (10) g b f h d f c g e a

II.

A (9) f b e g d h c a g
B (11) e a g b h c f d h b f
C (13) d g e b f h b d a c f a d
D (5) f c g b e
E (7) f d h b g c g
F (12) b f d h e c f d a g e c
G (10) e a d g b h f c e b
H (8) h a f c e b g d
I (6) d a g c h e

III.

A (7) h e c a d g b
B (12) d f a g c f d h e b f g
C (6) d b h c a e
D (13) e h f c g a c e b f d g c
E (5) g c h f d
F (11) b e c a d h f g e a d
G (10) d h e b g c f a g f
H (8) g d h f b e a c
I (9) g d a f h e c f b

IV.

A (11) d h f c a g b h c e g
B (13) c f d a e g a c h d c e b
C (5) e b h a f
D (9) b e h d a f c g d
E (7) e c g b h a f
F (8) e b f a c h d g
G (6) h f b g e a
H (10) f d h c a g b e h d
I (12) e b h f c g a f b h d g

V.

A (8) g c h e b f d a
B (6) c a g b h f
C (12) e g b h d a f c e g f d
D (10) b e g a c f b h d g
E (13) g b h e a c e g d h b e a
F (5) b f c e g
G (11) d g e b f h c e a g f
H (7) b g d g e h c
I (9) h b f c g e d a c

VI.

A (12) c e h f b e g d a f h d
B (8) h b e a f d g c
C (9) h f b e g d a f c
D (6) e c g a f d
E (13) f a g d h d b f c a e g b
F (10) c a d h e b g f c e
G (11) c f d h b e g a d f c
H (7) h f c e a g b
I (5) e b h f d

VII.

A (6) b h e c a g
B (8) b g a f h e c g
C (10) h f a d b e c g a f
D (12) g a d b f d a e h f g c
E (9) d h b e g a c h f
F (13) h c a f d f b h e b g c h
G (5) c g b h a
H (11) e h f g c h d a f b g
I (7) c a e g f h b

VIII.

A (9) g a e c g d h f b
B (10) g c f b e h d a f b
C (8) c f g a d b h e
D (6) f d h b e c
E (12) h b e c g b f a e d g f
F (7) g e b f c a d
G (13) d b f g c e g a f g e b f
H (5) d h b f c
I (11) f a g e c h b f a d g

IX.

A (10) e h b f c g a d h c
B (7) b f d h e a c
C (12) f h c a e g f h a d b e
D (11) h d b g a e b f h d f
E (5) h e b g c
F (8) f h e g c a d h
G (9) f c h e b d g c a
H (6) c h a e b f
I (13) d f b a e g d c h b f e c

X.

A (5) c h e f b
B (10) f b g a h e c f d g
C (7) c g e a h f d
D (11) g c a d g e b f h d e
E (9) c a g f d h f b e
F (6) g e a c h b
G (12) c e g e a g b h f a d b
H (13) c e c h d f h b g e b f d
I (8) b e c f h d g a

EXPERIMENT 43.—WORD MEMORY

The words at the bottom of each list may be substituted for those starred, to make a study of the effect of repetition on memory. If the starred words are used, *bread* and *car* will each occur twice, *glass* and *nine* each three times, and *song* and *hold* each four times.

turn	shoe	hair	rust	hill
full	yard	tie	cream	dust
ball	it	mat	tip	fan
late	nine	tape	card	art
ink	map	stamp	band	fuse
wild	go	tree	seed	cake
rare	young	cup	pound	sock
book	date	old	roof	ounce
bread	light	cage	air	work
see	sit	tire	farm	girl
run	rich	bronze	fur	arch
are	lake	sand	tool	line
glass	wire	wheel	shot	tick
rain	sky	rose	clock	flow
four	hall	west	all	duck
dog	ring	blow	trunk	pad
cap	wood	hold	horn	jump
road	child	fence	new	ream
flag	dress	ten	ant	ice
car	rug	glove	coil	quake

tell	brush	mint	suit	bark
can	team	fan	nut	ape
pole	ham	blade	pump	nun
bell	may	link	mow	peach
lock	hit	ride	sun	hear
nail	jar	bleak	vane	right
well	dry	floor	heat	rack*
post	lunch***	paint	cod	run
range	golf	sash	cross	six
boot	comb	rug**	pin	need
soap	kite*	bake	green	felt**
pull	peat	tea	port**	blue
back***	rage	box	jilt	word
top	wrist	skim	case	sour***
net	slate	valve	fly	elm
rub*	hand	tin	arm	frame
fry	gift	base	seat	gem
root	bar	tent	oil	tan
part	silk***	belt***	cord	joint
boy**	meat	wax	dust***	creek

song***	hold***	song***	hold***	glass**
nine**	song***	hold***	song***	hold***
bread*	car*	glass**		nine**

EXPERIMENT 44.—A STUDY OF RECOGNITION

1.	car	green	base	fence	bronze
2.	wood	jilt	tent	rose	hit
3.	kind	age	zone	ode	fare
4.	veil	lap	once	vice	blot
5.	mad	neat	clear	off	hard
6.	dress	arm	valve	glove	range
7.	four	sun	gift	young	soap
8.	glass	oil	comb	lake	dry
9.	ace	rear	job	use	mode
10.	fleece	key	wind	name	very
11.	rain	mow	pin	tell	jar
12.	are	floor	gem	pole	peat
13.	joke	inch	act	mean	whirl
14.	lace	dark	nice	chime	tuck
15.	dip	hang	quack	inn	pass
16.	hall	cross	cod	meat	can
17.	child	fly	nun	part	well
18.	dog	six	link	fry	root
19.	gash	glare	weak	let	jerk
20.	eat	all	dock	weed	bib
21.	fan	turn	full	dust	late
22.	bell	hair	tie	art	nine
23.	heart	fact	meek	lamb	grace
24.	ear	bet	care	rap	end
25.	gap	give	lute	cur	knife
26.	net	shoe	yard	mat	tip
27.	boot	rust	cream	card	band
28.	hand	coil	it	ball	seed
29.	ill	not	kick	quail	cave
30.	cash	rant	beak	vein	jail
31.	golf	book	date	old	roof
32.	bar	ounce	see	tire	sit
33.	day	fog	each	wear	up
34.	know	lamp	red	orb	pinch
35.	leak	scour	nick	deed	beg
36.	bake	clock	ream	ant	rare
37.	skim	trunk	quake	shot	ink
38.	mint	new	hill	cup	light
39.	add	ire	jack	few	owl
40.	just	faint	dirt	but	make

The old and new words occur in the following order: 1. old; 2. old; 3. new; 4. new; 5. new; 6. old; 7. old; 8. old; 9. new; 10. new. Each series of ten words in the different columns is composed of old and new words in the same relative positions.

EXPERIMENT 45.—MEASURING THE AMOUNT FORGOTTEN

Either of the following series of nonsense syllables may be used for the experiment.

Series A		*Series B*	
1.	gid	1.	mig
2.	lor	2.	dur
3.	zir	3.	lut
4.	vab	4.	mer
5.	mej	5.	lif
6.	tiv	6.	jub
7.	kar	7.	pol
8.	sov	8.	kep
9.	jer	9.	nir
10.	taz	10.	woz
11.	guf	11.	pim
12.	teg	12.	mux
13.	dak	13.	ces
14.	nad	14.	bex
15.	gur	15.	lat
16.	yar	16.	gen
17.	pos	17.	tig
18.	tif	18.	rog
19.	rel	19.	vof
20.	jik	20.	bux

EXPERIMENT 46.—DOMINANT TYPE OF IMAGERY

Stimulus Words and Phrases

1. fog
2. hat
3. sun
4. cat
5. clay
6. solo
7. camp
8. rain
9. silk
10. taxi
11. nuts
12. stamp
13. radio
14. glove
15. storm
16. waves
17. brush
18. watch
19. store
20. river
21. movie
22. piano
23. towel
24. onion
25. knife
26. sugar
27. Wilson
28. picnic
29. violin
30. banana
31. meadow
32. letter
33. pencil
34. rowing
35. candle
36. sparrow
37. running
38. charity
39. quinine
40. perfume
41. whistle
42. newsboy
43. gasoline
44. swinging
45. mosquito
46. throwing
47. magazine
48. umbrella
49. headache
50. laughing
51. Christmas
52. telephone
53. ice cream
54. door knob
55. thumb nail
56. typewriter
57. dining room
58. popping corn
59. bruised hand
60. carrying ice
61. railway coach Visual
62. telegraph key
63. lifting bundle
64. cranking a car
65. wind in night
66. coffee boiling
67. a crying child
68. a circus parade
69. pushing on door
70. crowd down town
71. shelling peanuts
72. dismissal of class
73. tight fitting shoe
74. reading in library
75. clerk wrapping bundle
76. conductor of orchestra
77. holding parasol in wind
78. attending church service
79. electric light
80. saw cutting wood

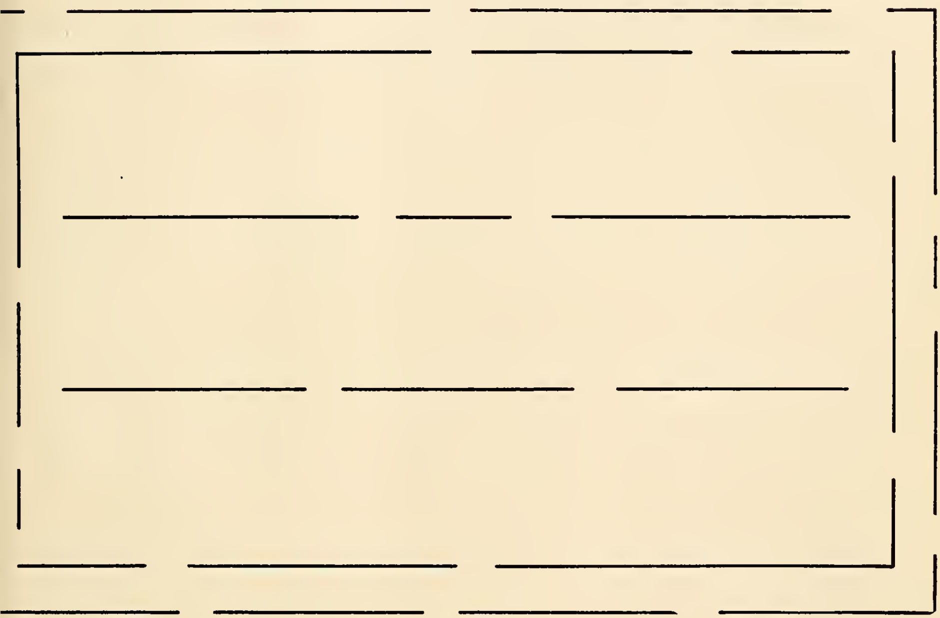
EXPERIMENT 47.—USING RECALLED FACTS

1.	38479	13.	28615
2.	25683	14.	38165
3.	31694	15.	47139
4.	85326	16.	85714
5.	71294	17.	26317
6.	27541	18.	39158
7.	49537	19.	41376
8.	37192	20.	18742
9.	58346	21.	31875
10.	74925	22.	69781
11.	83169	23.	35194
12.	49517	24.	87352
		25.	95368

1.	473829	13.	257319
2.	316247	14.	328746
3.	953261	15.	956317
4.	491527	16.	387524
5.	538624	17.	478269
6.	371925	18.	521794
7.	251874	19.	387961
8.	731982	20.	754219
9.	274861	21.	369428
10.	379625	22.	598621
11.	483719	23.	374186
12.	354192	24.	713845
		25.	942573

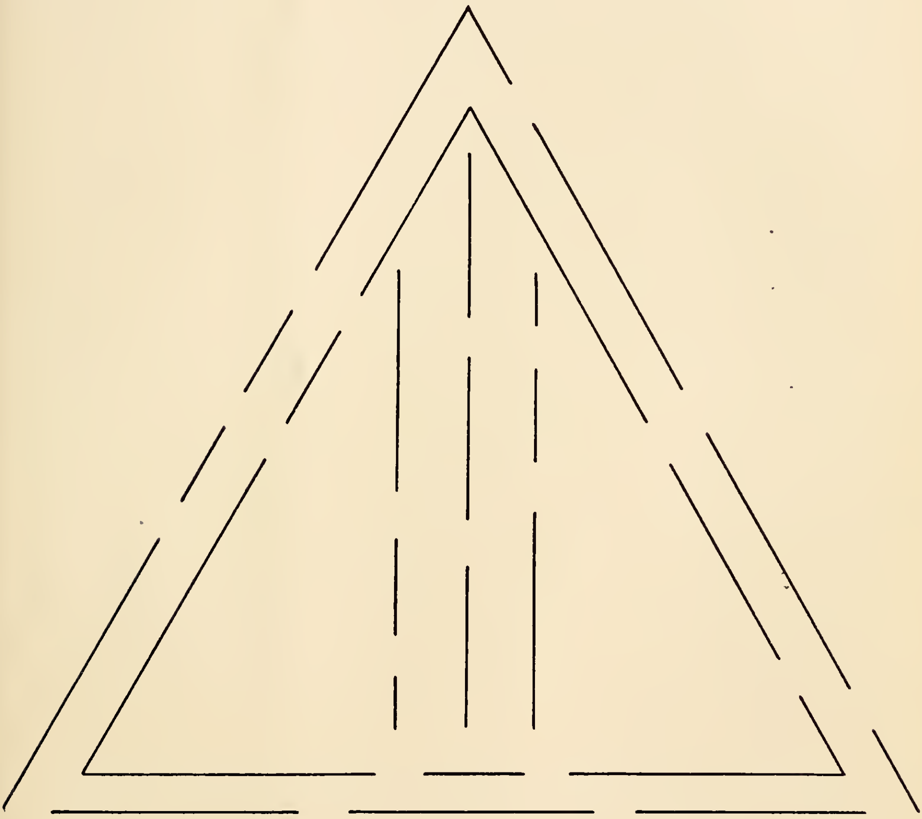
EXPERIMENT 48.—RECALL OF PATTERNS

Part A: Rectangle



EXPERIMENT 48.—RECALL OF PATTERNS

Part B: Triangle



8	2	6	2	5	1	4	1	9	7	3	9	4	7	3	2	3
7	9	9	1	8	3	3	4	2	8	2	5	3	4	4	7	9
6	4	4	8	6	5	2	5	5	9	7	8	8	8	7	8	5
2	5	9	3	9	8	5	2	4	7	6	2	9	5	2	3	6
4	7	8	6	4	7	9	9	6	5	1	5	7	9	6	5	7
3	**4**	**3**	**7**	**9**	**2**	**6**	**3**	**7**	**8**	**7**	**4**	**2**	**3**	**9**	**6**	**2**
9	8	6	1	2	9	8	7	8	3	4	7	8	6	8	2	4
3	3	7	8	7	2	7	1	9	4	3	9	5	3	5	7	2
5	4	2	7	5	4	6	3	6	8	6	3	7	1	4	8	6
7	9	5	9	3	8	1	8	3	3	8	7	6	9	7	3	7
3	6	3	3	9	6	8	7	4	2	3	2	3	6	1	6	4
4	**7**	**8**	**7**	**6**	**2**	**4**	**2**	**6**	**7**	**9**	**6**	**6**	**4**	**6**	**8**	**2**
8	2	9	8	7	7	3	9	7	4	6	1	2	7	9	5	3
4	4	3	5	1	9	5	3	9	2	9	8	6	5	5	4	5
9	9	6	3	6	3	3	2	8	6	4	6	8	3	8	9	7
6	6	8	6	3	2	5	6	5	8	7	8	9	2	4	4	9
4	3	6	8	1	4	2	3	2	9	8	7	9	7	8	6	3
7	**9**	**4**	**2**	**7**	**2**	**4**	**6**	**3**	**4**	**2**	**6**	**3**	**2**	**3**	**1**	**4**
3	2	8	3	9	8	9	8	6	7	5	3	2	3	5	9	1
8	4	6	4	7	6	7	7	9	8	7	1	4	9	1	6	7
9	8	3	7	5	1	8	6	4	6	2	7	7	2	3	1	6
8	6	4	8	3	5	3	2	3	9	9	6	9	7	6	3	4
1	3	5	6	9	8	3	2	9	6	3	8	5	4	7	9	2
7	**8**	**3**	**9**	**4**	**2**	**7**	**3**	**6**	**9**	**4**	**2**	**5**	**3**	**6**	**2**	**7**
5	3	5	3	6	8	4	8	8	1	7	6	7	7	4	7	9
2	9	8	4	2	5	2	3	3	5	8	6	8	9	9	4	5
4	8	7	7	9	6	6	5	4	7	3	9	3	3	2	3	7
7	4	2	9	4	2	8	7	9	8	2	3	8	6	6	8	8
9	1	3	3	3	7	1	1	2	4	4	1	6	2	8	9	7
6	**4**	**6**	**7**	**9**	**8**	**4**	**6**	**7**	**3**	**6**	**7**	**3**	**4**	**9**	**2**	**4**
7	8	7	4	1	2	6	9	5	3	9	2	6	9	8	5	9
2	3	3	3	7	9	2	8	7	5	2	4	5	3	3	4	6
5	9	6	6	4	7	5	9	6	4	5	3	8	5	6	9	5
9	7	8	7	2	9	8	6	3	2	8	8	7	2	9	7	2
3	6	7	9	6	6	7	8	8	3	9	6	2	8	6	6	8
4	**7**	**3**	**6**	**2**	**4**	**3**	**3**	**7**	**6**	**7**	**2**	**4**	**6**	**7**	**8**	**3**
8	6	1	2	4	8	4	4	6	4	6	4	8	2	1	9	7
1	2	8	2	6	2	6	1	5	5	1	2	4	8	3	9	5
7	6	7	9	4	4	1	3	8	9	3	5	7	6	8	4	2
2	4	6	2	3	7	9	8	3	4	6	2	3	3	7	7	5
3	8	4	7	6	3	6	3	8	7	9	6	7	7	3	3	4
6	**4**	**3**	**2**	**7**	**4**	**2**	**9**	**3**	**8**	**4**	**7**	**6**	**2**	**4**	**1**	**2**

APPENDIX C.—BLANKS FOR RECORDS

STUDENT'S NAME ....DATE ....

EXPERIMENT ....

No.	Score	d	d^2	Com.	No.	Score	d	d^2	Com.
1					26				
2					27				
3					28				
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25					50				

SUM.......................... MEAN.......................... SD.......................... V...................

Student's Name ....Date ....

Experiment ....

No.	Score	d	d^2	Com.
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No.	Score	d	d^2	Com.
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Sum.......................... Mean.......................... SD.......................... V...................

STUDENT'S NAME ....DATE ....

EXPERIMENT ....

No.	Score	d	d²	Com.	No.	Score	d	d²	Com.
1					26				
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SUM........................ MEAN........................ SD........................ V...................

STUDENT'S NAME .... DATE ....

EXPERIMENT ....

No.	Score	d	d^2	Com.
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SUM........................ MEAN........................ SD........................ V..................

Student's Name .... Date ....

Experiment ....

No.	Score	d	d^2	Com.
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Sum........................ Mean........................ SD........................ V....................

Student's Name .... Date ....

Experiment ....

No.	Score	d	d^2	Com.	No.	Score	d	d^2	Com.
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Sum........................ Mean........................ SD........................ V...................

Student's Name .... Date ....

Experiment ....

No.	Score	d	d^2	Com.	No.	Score	d	d^2	Com.
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Sum.......................... Mean.......................... SD.......................... V....................

STUDENT'S NAME ....DATE ....

EXPERIMENT ....

No.	Score	d	d^2	Com.	No.	Score	d	d^2	Com.
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SUM......................... MEAN......................... SD......................... V...................

STUDENT'S NAME .... DATE ....

EXPERIMENT ....

No.	Score	d	d²	Com.	No.	Score	d	d²	Com.
1					26				
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SUM........................ MEAN........................ SD........................ V....................

STUDENT'S NAME .... DATE ....

EXPERIMENT ....

No.	Score	d	d^2	Com.	No.	Score	d	d^2	Com.
1					26				
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25					50				

SUM........................ MEAN........................ SD........................ V..................

UDENT'S NAME .... DATE ....

PERIMENT ....

Score	d	d^2	Com.

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SUM.......................... MEAN.......................... SD.......................... V....................

Student's Name .... Date ....

Experiment ....

No.	Score	d	d^2	Com.
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Sum.......................... Mean.......................... SD.......................... V....................

STUDENT'S NAME .... DATE ....

EXPERIMENT ....

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SUM.......................... MEAN.......................... SD.......................... V..........................

Student's Name .... Date ....

Experiment ....

No.	Score	d	d^2	Com.	No.	Score	d	d^2	Com.
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25					50				

Sum.......................... Mean.......................... SD.......................... V.....................

Student's Name ....

CLASS SUMMARY

Name	Exp..............			Exp..............			Exp..............			Exp..............		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

[*Continued on reverse side*]

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

TUDENT'S NAME ....

CLASS SUMMARY

Name	Exp.______			Exp.______			Exp.______			Exp.______		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

[*Continued on reverse side*]

Name	Exp..........			Exp..........			Exp..........			Exp..........		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

Student's Name ....

CLASS SUMMARY

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

[*Continued on reverse side*]

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

STUDENT'S NAME ....

CLASS SUMMARY

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

[*Continued on reverse side*]

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

Student's Name ....

CLASS SUMMARY

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

[*Continued on reverse side*]

Name	Exp.			Exp.			Exp.			Exp.		
	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V	Lev.	Var.	V

tudent's Name ....

PERSONAL DATA

Function or Structure	Exp. No.	Level	Position	Var.	Position

[*Continued on reverse side*]

Function or Structure	Exp. No.	Level	Position	Var.	Position